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Studies on Assessment of water Quality and Hydrological behaviour using Physico- chemical Parameters of surface water of Glacial fed Mountainous Goriganga river in Kumaun Himalaya-I

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Abstract

Glacial fed rivers are vital fresh water systems that are critical for the sustenance of life. The present study was carried to access the quality of water and hydrological behaviour using physico-chemical parameters of surface water of glacial fed mountainous Goriganga River in Kumaun Himalaya. Study was conducted between Jauljibi to Madkot with in a river stretch of 44kms. Surface water samples were collected for the analysis of quality of water from three sampling stations (Station1-Jauljibi-600msl; Station2-Baram- 900msl and Staion3-Madkot-1300msl). A total of 12 water quality parameters such as: Ambient temperature, water temperature, conductivity, pH, alkalinity, carbonate, bicarbonate, free carbon dioxide, dissolved oxygen, velocity, acidity and water hardness were monitored from July-2006 to June-2008 for a period of two years. The studies on the analysis of water quality parameters of Goriganga river showed that ambient temperature fluctuated between 11.5^{0}C to 32.7^{0}C and 11.0^{0}C to 32.0^{0}C; water temperature 7.1^{0}C to 18.9^{0}C and 7.5^{0}C to 20.0^{0}C; Conductivity 0.131 µScm^{-1} to 0.361 µScm^{-1} and 0.058 µScm^{-1} to 0.322 µScm^{-1}; pH 7.0 to 8.87 and 7.0 to 8.5; Alkalinity 62 mg/l to 190 mg/l and 84 mg/l to 180mg/l; Bicarbonate 62.0 mg/l to 180.0 mg/l and 84.0 mg/l to 170.0 mg/l; Free Carbon dioxide zero or absent to 6.0; Dissolved Oxygen 5.6 mg/l to 12.0 mg/l and 6.4 mg/l to 16.8 mg/l; Velocity 0.52 m/sec to 1.72 m/sec and 0.47 m/sec to 1.61 m/sec; Acidity 5.0 mg/l to 30.0 mg/l and 5.0 mg/l to 40.0 mg/l and water hardness 80.0 mg/l to 166 mg/l and 90.0 to 198.0 mg/l during first year (2006-07) and second year (2007-08) respectively. Carbonate at all the selected stations in the Goriganga river remained below the detection limit or mostly absent except few months. Assessment of water quality parameters at the three selected sampling station in the Goriganga river has shown that the water at the surface level was well within the permissible limits prescribed by ISI, ICMR and WHO drinking water standards and the ecological situation in this region is stable, favourable and promising at the present time. Statistically, the correlation between different selected water quality parameters have also been drawn and discussed in the present paper.

Keywords: Assessment, water quality, physico-chemicals, hydrological, Goriganga, Kumaun Himalaya.

Introduction

The well known axiom of biology is that, "The fire of life burns only in water". Water is undoubtedly the Humankind's most important resources in life. No matters how rich a person is? Without water he or she cannot live because water is both the least expensive and most essential commodities used by humans. Water occupies a central role in the transport of chemicals around the surface of our planet Earth. Although its appearance is bland and has certain properties that makes it unique. As the water is the most important component of ecosystem, any imbalance created in terms of quality (which is the presence of impurities added to it) can hard the whole ecosystem. Physico-chemical parameters play a vital role for providing information about the water bodies and are expected to serve as tools for assessing their suitability for fish culture and human consumption. It is a fact that good water quality produces healthier humans than one with poor water quality. Nevertheless individual variations of water bodies caused by anthropogenic influences or variations in bottom structure and chemistry are other important features that bring drastic changes in medium and causes deterioration effects on biota in general and fish in particular (i.e. the physico-chemical characteristics of a water body exerts great effects on its biota). The wide fluctuations in abiotic variables have significant impact on biotic life. Lotic water bodies which are characterized by a continual downstream movement of dissolved substances a suspended material results in dynamic interaction between components of ecosystem. Human activities had been a major factor for creating most serious problems of water contamination and pollution. By the middle of 19th century most of the rivers become polluted and deterioration in water quality of surface water has become a matter of serious concern across the world and initiation of hydrobiological investigations taken place. The Kumaun region lies between latitudes, 28^0 44″ to30^0 49″ N and longitudes 78^0 45″ to 81^0 5″ E. The peaks and valleys of Kumaun were well known in ancient times as the abode of Gods and Goddesses and source of the Ganga river.

Among many large rivers, the Goriganga River is lying in Munsiyari Tehsil of the Pithoragarh District, part of Uttarakhand state in north India, falls between the latitudes 29˚ 45′ to 36˚ 36′ N and longitudes 79˚ 59′ to 80˚ 45′. The Goriganga river originates Milam glacier (3600 msl). Water from surface sources provides sustenance to plants and animals and constitutes the habitat for aquatic organisms and meets importance of agriculture and industrial needs. Many workers have worked on the assessment of water quality by conducting physico-chemical and biological analysis[1-10]. In the present study an attempt was made to assess the quality of water and hydrological behaviour using physico-chemical parameters of surface water of glacial fed mountainous Goriganga river.

Material and Methods

Physiography of the River: The Goriganga river originates from a dual source in a glacier near south of Untadhura ridge feeding the eastern branch and another glacier near Milam (3600 msl) feeding the western branch. The basin of Goriganga river is located in eastern Kumaun Himalaya ranges of Pithoragarh district and falls between the latitudes 29˚ 45′ to 36˚ 36′ N and longitudes 79˚ 59′ to 80˚ 45′ and forms remote part of Uttarakhand state. The breath taking beauty of Uttarakhand Himalaya, wide expenses of grassy meadow, perennial rivers roaring down the zig-zag course, a stupendous variety of flora and fauna, above all, pure nature unsullied, seem to beckon the beholder in to their folds in to a charmed world of virgin beauty. The total catchment area of the river is about 2230 sq.km. Out of which 346 sq.km. is snowbound[11].

Goriganga river is fed by numerous small ghaderas (Routis gad, Kwiri, Jimba gad, Pina gad, Pyunshi gadhera, Gokhla gad etc.), few big tributaries (Gossi gad –joins Goriganga at Baram; Shera gad–joins Goriganga at Shera ghat and Mandakni joins Goriganga at Madkot), hot springs and various seasonal nallahs and finally joins Kali river at Jauljibi which then defines Indo-Nepal boundary.

The Goriganga valley is bound in the North by the Tibetan plateau and in the south-east by the kingdom of Nepal which is separated by river Kali. The valley represents three geological sub-divisions i,e lesser, greater and trans-Himalaya and is divided in to two parts; the upper Gori valley or Malla Johar and the lower Gori valley. The whole stretch of valley is about 100 km. and the Goriganga river runs through the entire length of the valley. The Goriganga valley is a remote part of Uttatakhand state, where access by road is very limited.

Sampling and Analysis: Water samples were collected for physico-chemical analysis from three different sampling stations i.e. sampling station-1, Jauljibi (600MSL); sampling station -2, Baram (900MSL) and Sampling station -3, Madkot (1300MSL) figure-1. Monthly water samples were collected once in every month from July 2006 to June, 2008 for a period of two years. In order to maintain uniformity in physico-chemicals throughout the study period, the samples from three sampling station were collected from surface layers between 4-5 p.m at station-1; 9-10 a.m at station -2 and 3-5 p.m at station–3 during the last week of each month. Some physico-chemical characteristics like free Co_2, D.O, pH, temperature, velocity, conductivity have been determined at the sampling stations and for other chemical parameters, water samples were brought to the laboratories of Zoology Department S. S. J. Campus Almora for analysis according to the conventional standard methods of APHA[12], Adoni[13], Welch[14], Michael[15] and Trivedy and Goel[16]. The data of physico-chemical characteristics were analyzed statistically for getting mean, standard deviation and correlation co-efficient among them Prasad[17].

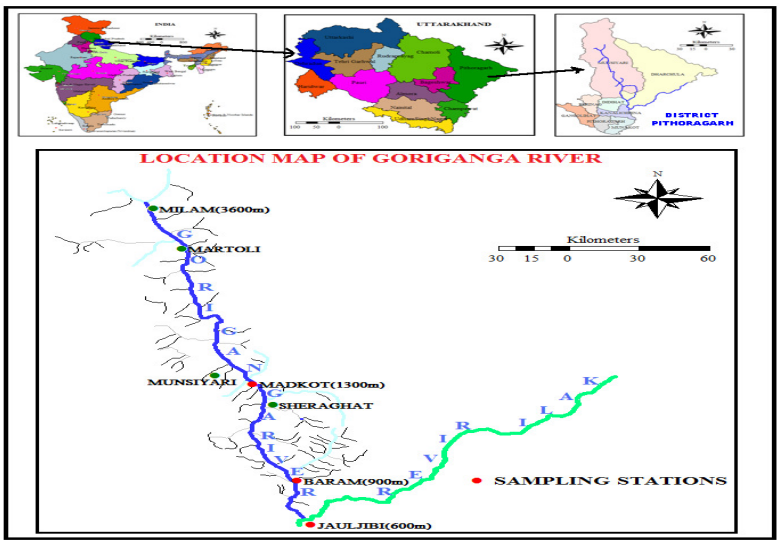

Figure-1
Location map showing the three sampling stations, Jauljibi-1 (600 msl), Baram-2 (900 msl) and Madkot-3 (1300 msl) in the Gorigana River of Kumaun Himalaya

Results and Discussion

Ambient Temperature: The ambient temperature varies monthly, seasonally, yearly and altitudinally at different sampling stations in the catchment area of Goriganga river tables-1, 2 and figures-2, 3, 4, 5. The ambient temperature ranged from 11.5^{0}C to 32.7 ^{0}C in the first year (2006-07) and 11.0 ^{0}C to 32.0^{0}C in the second year table-1 and figures-2, 3. In the present study it was observed that the highest seasonal mean values of ambient temperature (30.1 ^{0}C, 28.97^{0}C and 24.17^{0}C) were recorded in monsoon season whereas the lowest (19.3^{0}C, 18.9^{0}C and 14.85^{0}C) values were recorded in winter season at spot-1, spot-2 and spot-3, respectively during 2006-07, table 2; while it was the highest in monsoon season (29.0^{0}C and 27.12^{0}C) at spot-1 and spot-2 and (23.37^{0}C) in summer at spot-3 and the lowest values (17.95^{0}C, 17.0^{0}C and 13.75^{0}C) were recorded in winter at spot-1, spot 2 and spot-3, respectively in the second year table-2. The highest annual mean values of ambient temperature (24.64^{0}C and 23.96^{0}C) were recorded at spot-1 (Jauljibi) and the lowest annual mean values (19.22^{0}C and 19.62^{0}C) were recorded at spot 3 (Madkot) during first and second year (2006-07 and 2007-08), respectively in the present study table-1. It was also observed that ambient temperature in the catchment area of Goriganga river was higher in second year (2007-08) than the previous year (2006-07) and altitudinally, the ambient temperature increases from upstream to downstream in the present study table-1. The ambient temperature showed a positive significant correlation (r=0.91563 and r=0.888236) with water temperature figures-6, 7, (r = 0.903467 and r = 0.724711) with velocity of water figures 8, 9 and (r = 0.687907 and r = 0.538506) with free CO_2 figures-10, 11 in the first year (2006-07) and in the second year (2007-08), respectively. While it showed negative significant correlation (r=-0.9319 and r=-0.90573) with dissolved oxygen figures-12, 13 first year (2006-07) and second year (2007-08), respectively in the present study.

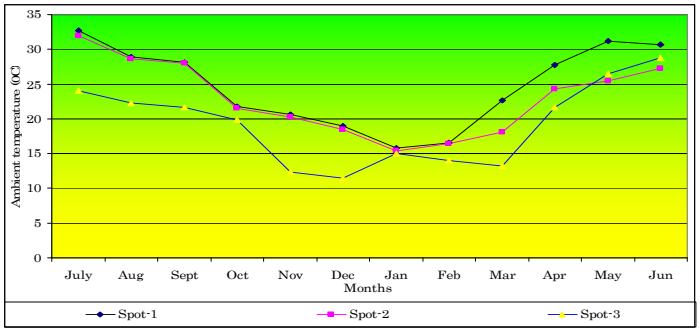

Figure-2
Monthly variations in ambient temperature at three spots in the Goriganga river during 2006-07

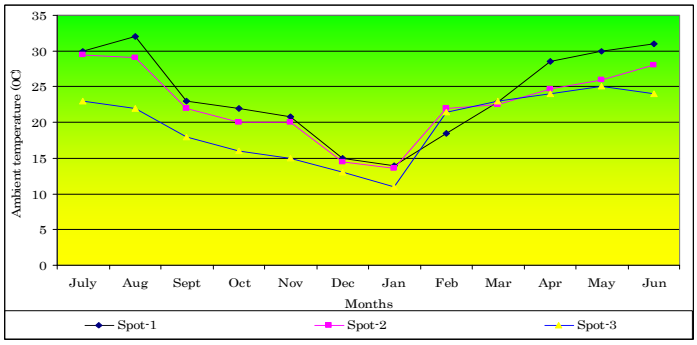

Figure-3
Monthly variations in ambient temperature at three spots in the Goriganga river during 2007-08

Table-1
Monthly variations in ambient temperature at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Ambient Temperature (^{0}C)					
	July -2006-June- 2007			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
July	32.7	32.0	24.0	30.0	29.5	23.0
Aug	28.9	28.6	22.3	32.0	29.0	22.0
Sept	28.1	28.0	21.6	23.0	22.0	18.0
Oct	21.8	21.5	19.8	22.0	20.0	16.0
Nov	20.6	20.2	12.3	20.8	20.0	15.0
Dec	19.0	18.5	11.5	15.0	14.5	13.0
Jan	15.8	15.4	15.0	14.0	13.5	11.0
Feb	16.5	16.4	14.0	18.5	22.0	21.5
Mar	22.7	18.1	13.2	22.8	22.5	23.0
Apr	27.7	24.3	21.7	28.5	24.7	24.0
May	31.2	25.4	26.5	30.0	26.0	25.0
Jun	30.7	27.3	28.8	31.0	28.0	24.0
Mean	24.64	22.97	19.22	23.96	22.64	19.62
S.D.	5.943	5.384	5.862	6.275	5.190	4.810

Table-2
Seasonal variations in Ambient Temperature (^{0}C) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Seasons	(A): Ambient Temperature (^{0}C)					
	2006-07			2007-2008		
	Spot-1	Spot-2	Spot-3	Spot-1	Spot-2	Spot-3
Monsoon	30.1	28.97	24.17	29.0	27.12	21.75
Winter	19.3	18.9	14.85	17.95	17.0	13.75
Summer	24.52	21.05	18.8	24.95	23.8	23.37

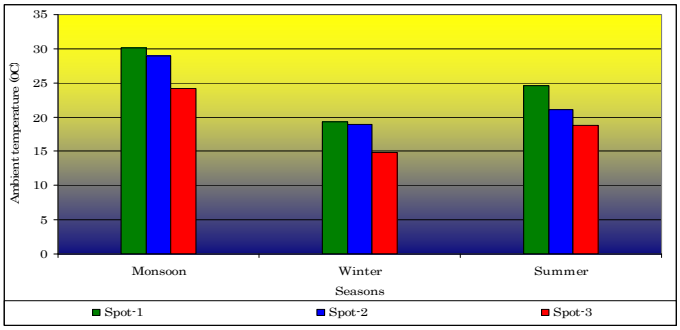

Figure-4
Seasonal variations in ambient temperature at three spots in the Goriganga river during 2006-07

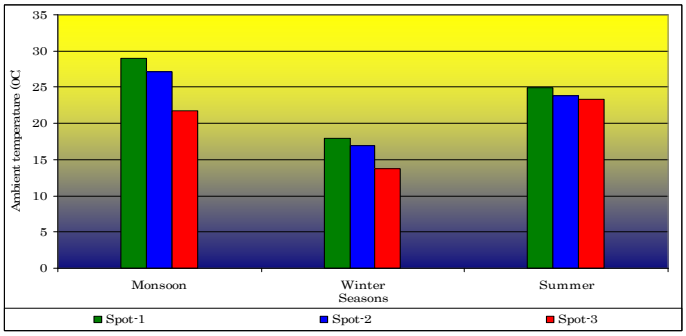

Figure-5
Seasonal variations in ambient temperature at three spots in the Goriganga river during 2007-08

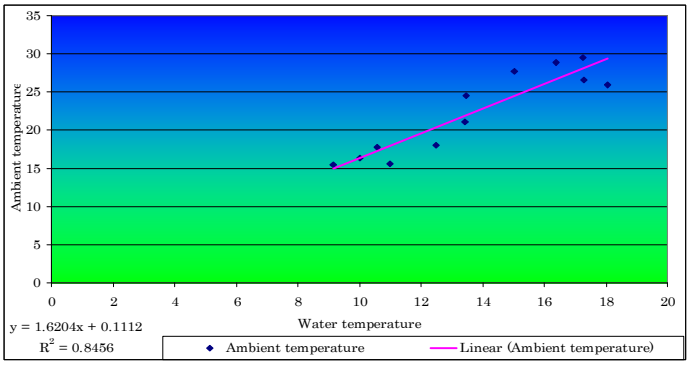

Figure-6
Correlation between ambient temperature and water temperature in the Goriganga river during 2006-07

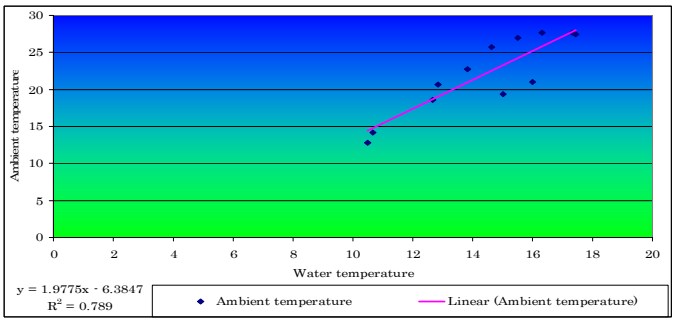

Figure-7
Correlation between ambient temperature and water temperature in the Goriganga river during 2007-08

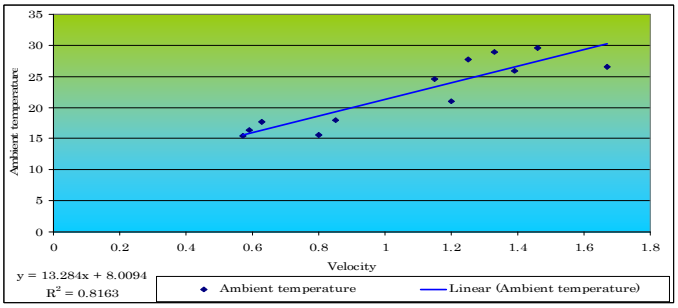

Figure-8
Correlation between ambient temperature and velocity of water in the Goriganga river during 2006-07

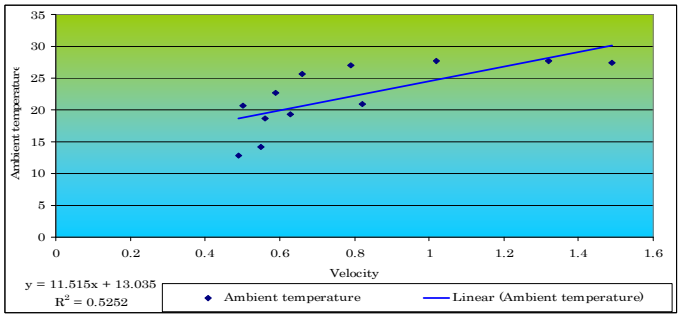

Figure-9
Correlation between ambient temperature and velocity of water in the Goriganga river during 2007-08

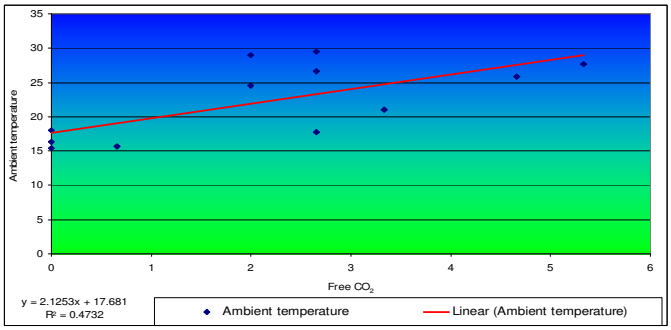

Figure-10
Correlation between ambient temperature and free CO_2 in the Goriganga river during 2006-07

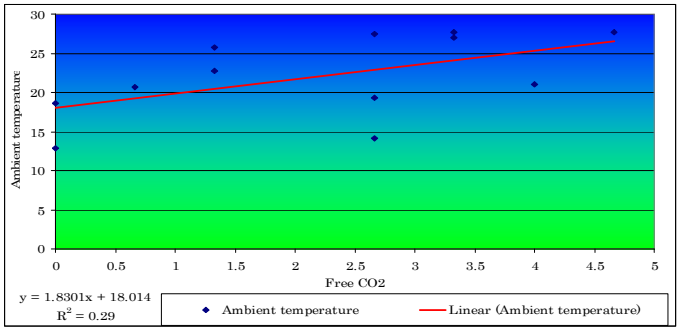

Figure-11
Correlation between ambient temperature and free CO_2 in the Goriganga river during 2008-09

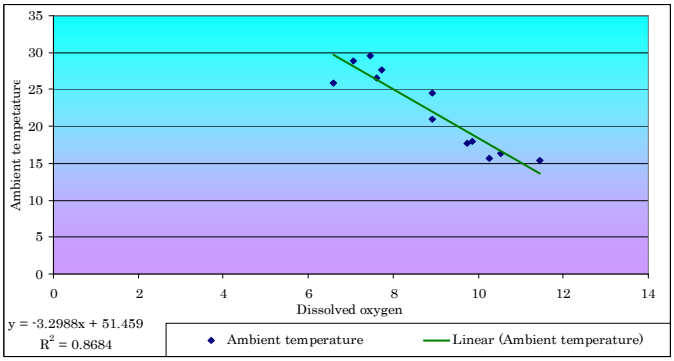

Figure-12
Correlation between ambient temperature and dissolved oxygen (D.O) in the Goriganga river during 2006-07

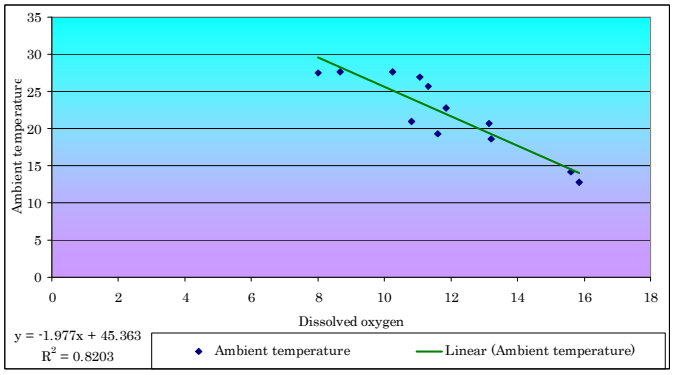

Figure-13
Correlation between ambient temperature and dissolved oxygen (D.O) in the Goriganga river during 2007-08

Water Temperature: The water temperature ranged from 7.1^{0}C to 18.9^{0}C in the first year (2006-07) and from 7.5^{0}C to 20.0^{0}C in the second year (2007-08) table-3 and figures-14, 15. The highest seasonal mean values of water temperature were recorded in monsoon season (18.07 ^{0}C, 17.37 ^{0}C and 16.32 ^{0}C) and (19.2^{0}C, 16.25^{0}C and 14.87^{0}C) while the lowest seasonal mean values of the parameter were recorded in winter season (13.15 ^{0}C, 10.55^{0}C and 8.67^{0}C) and (14.75^{0}C, 12.25^{0}C and 9.87^{0}C) at spot-1 (Jauljibi), spot-2 (Baram) and spot-3 (Madkot) during first year and second year, respectively table-4 and figures-16, 17. On the yearly basis, the highest annual mean (15.4^{0}C and 16.83^{0}C) of the water temperature was recorded at spot-1 (Jauljibi). While the lowest annual mean (12.06^{0}C, 12.25^{0}C) was recorded at Spot 3 (Madkot) during first and second year (2006-07 and 2007-8), respectively table-3 and figures-14, 15. Altitudinally water temperature increases from upstream to downstream in the river, Goriganga table-3. It was also observed that water temperature at surface level was higher in the second year (2007-08) than the previous year (2006-07) table-3 and figures-14, 15.

Water temperature showed positive significant correlation with free CO_2 (r=0.671261 and r=0.71903, figures-18, 19 and velocity of water (r=0.957946 and r=0.79697) figure-20, 21. While it showed negative significant correlation with dissolved oxygen (r=-0.96886 and r=-0.98445) figures-22, 23; alkalinity (r =-0.82622 and r=-0.80622) figures-24, 25 during first year (2006-07) and second year (2007-08), respectively in the present study.

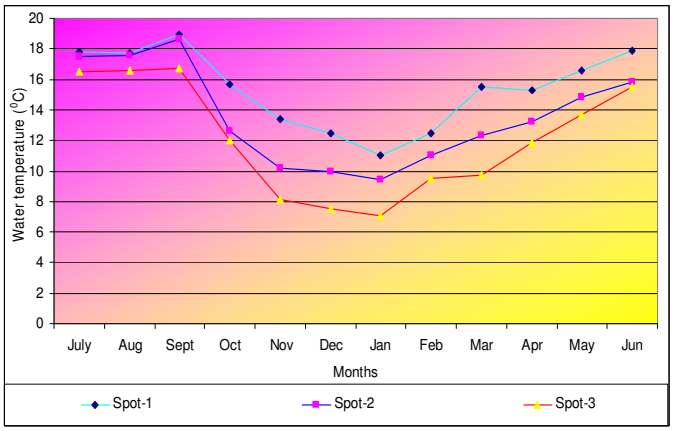

Figure-14
Monthly variations in water temperature at three spots in the Goriganga river during 2006-07

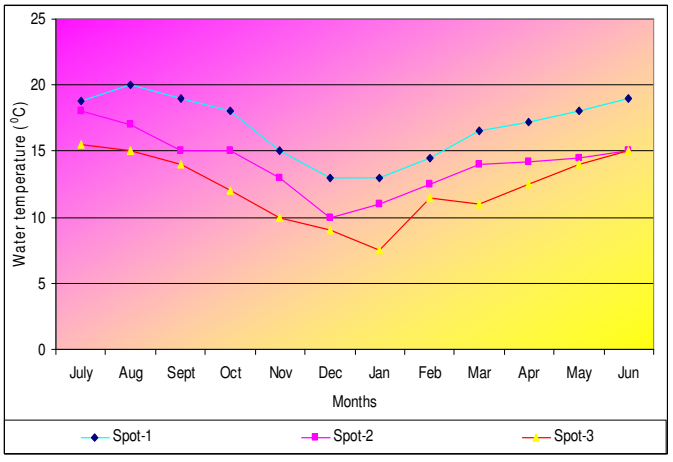

Figure-15
Monthly variations in water temperature at three spots in the Goriganga river during 2007-08

Table-3
Monthly variations in water temperature at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Water Temperature (^{0}C)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	17.8	17.5	16.5	18.8	18.0	15.5
Aug	17.7	17.6	16.6	20.0	17.0	15.0
Sept	18.9	18.6	16.7	19.0	15.0	14.0
Oct	15.7	12.6	12.0	18.0	15.0	12.0
Nov	13.4	10.2	8.1	15.0	13.0	10.0
Dec	12.5	10.0	7.5	13.0	10.0	9.0
Jan	11.0	9.4	7.1	13.0	11.0	7.5
Feb	12.5	11.0	9.5	14.5	12.5	11.5
Mar	15.5	12.3	9.7	16.5	14.0	11.0
Apr	15.3	13.2	11.9	17.2	14.2	12.5
May	16.6	14.8	13.7	18.0	14.5	14.0
Jun	17.9	15.8	15.5	19.0	15.0	15.0
Mean	15.4	13.58	12.06	16.83	14.1	12.25
S.D.	2.545	3.222	3.687	2.420	2.264	2.562

Table-4
Seasonal variations in Water Temperature (^{0}C) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Water Temperature(^{0}C)						
Season	2006-2007			2007-2008		
	Spot-	Spot-	Spot-	Spot-	Spot-	Spot-
Monsoon	18.07	17.37	16.32	19.2	16.25	14.87
Winter	13.15	10.55	8.67	14.75	12.25	9.87
Summer	14.97	12.82	11.2	16.55	13.8	12.25

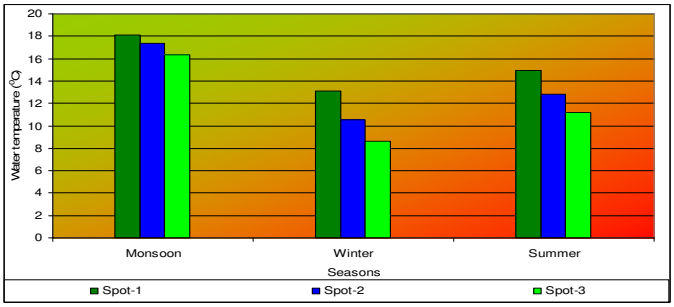

Figure-16
Seasonal variations in water temperature at three spots in the Goriganga river during 2006-07

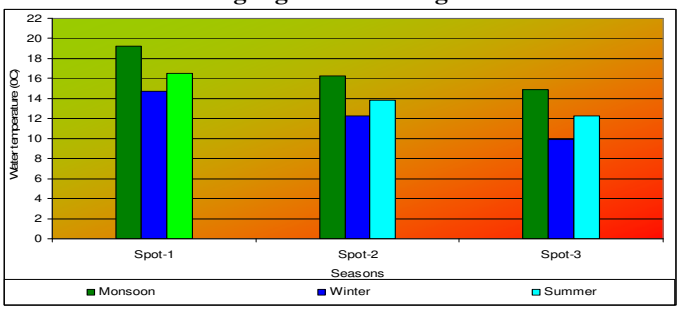

Figure-17
Seasonal variations in water temperature at three spots in the Goriganga river during 2007-08

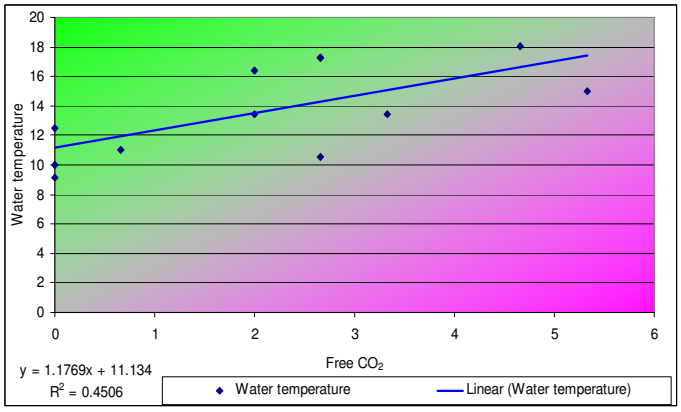

Figure-18
Correlation between water temperature and free CO_2 in the Goriganga river during 2006-07

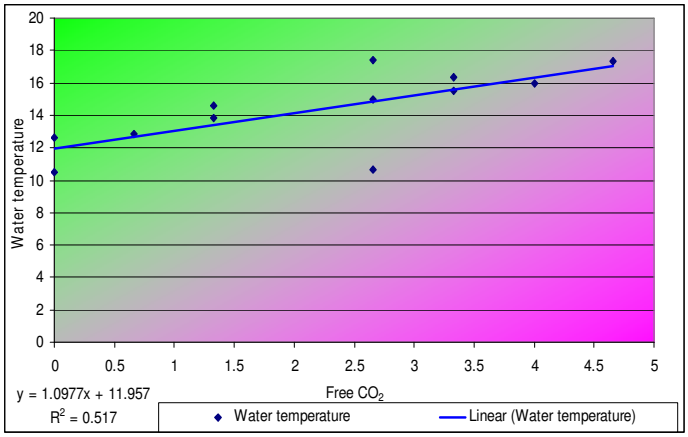

Figure-19
Correlation between water temperature and free CO_2 in the Goriganga river during 2007-08

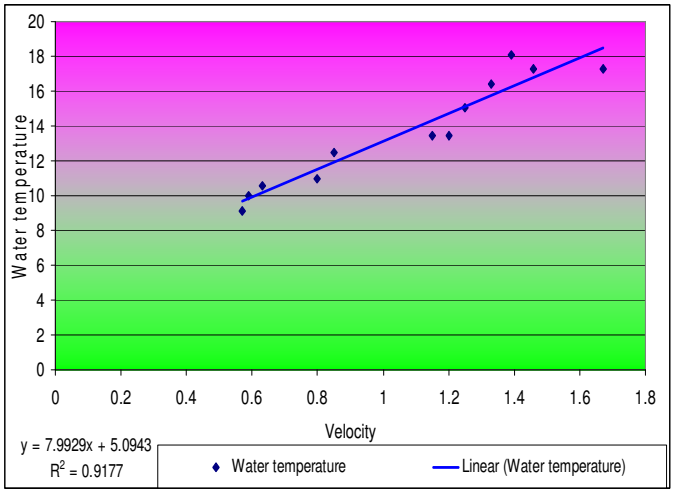

Figure-20
Correlation between water temperature and velocity in the Goriganga river during 2006-07

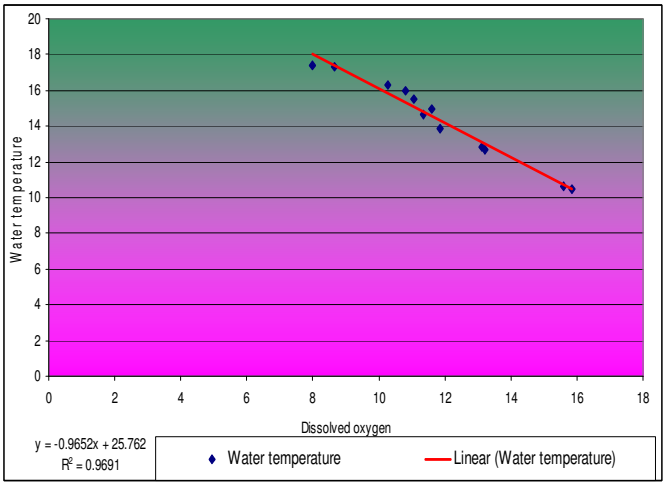

Figure-23
Correlation between water temperature and dissolved oxygen in the Goriganga river during 2007-08

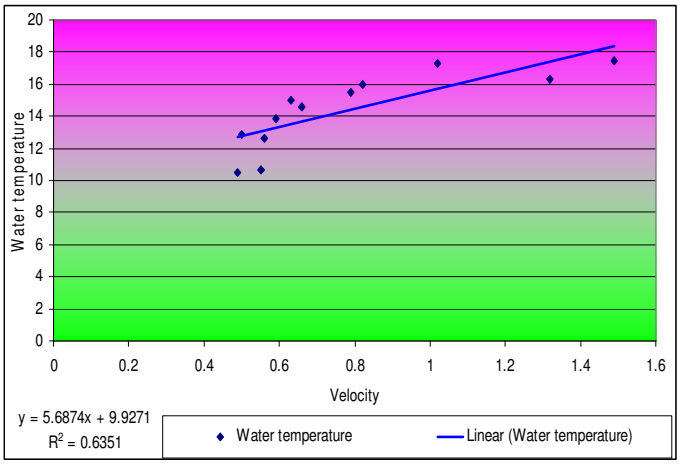

Figure-21
Correlation between water temperature and velocity in the Goriganga river during 2007-08

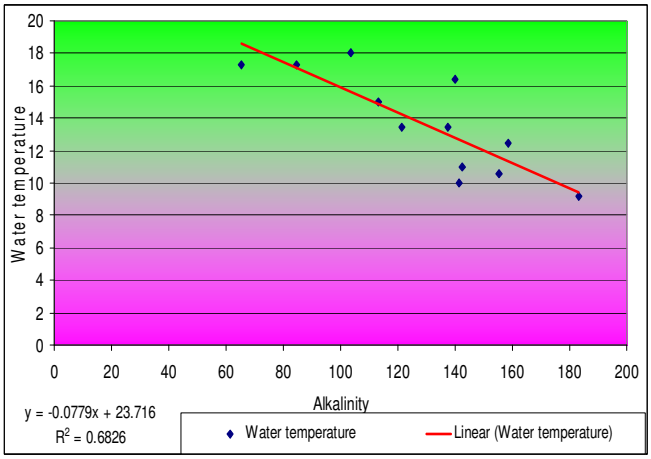

Figure-24
Correlation between water temperature and alkalinity in the Goriganga river during 2006-07

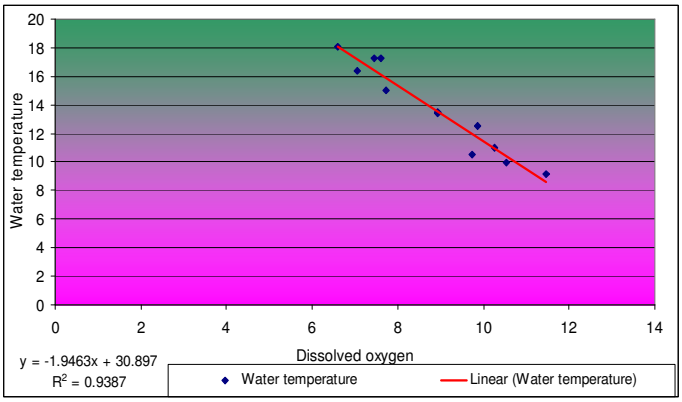

Figure-22
Correlation between water temperature and dissolved oxygen in the Goriganga river during 2006-07

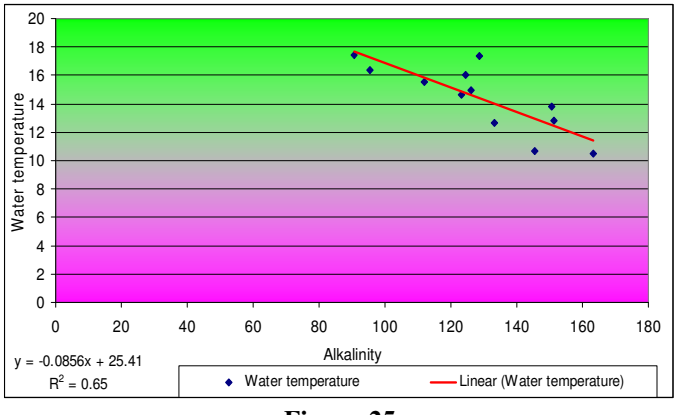

Figure-25
Correlation between water temperature and alkalinity in the Goriganga river during 2007-08

Conductivity: Conductivity of water depends upon the concentration of ions and the quality of its nutrients. Like other physico-chemical parameters, conductivity also showed monthly, seasonal and altitudinal variations in the water of a glacial fed mountainous Goriganga river of Kumaun Himalaya tables-5, 6 and figures-26, 27, 28, 29. The conductivity of Goriganga river was recorded in the range of 0.131 μScm^{-1} to 0.361 μScm^{-1} during first year (2006-07) and 0.058 μScm^{-1} to 0.322 μScm^{-1} during second year table-5 and figures-26, 27. During first year (2006-07), the values of conductivity fluctuated between 0.133 μScm^{-1} to 0.361 μScm^{-1} at Jauljibi, 0.139 μScm^{-1} to 0.358 μScm^{-1} at Baram and 0.131 μScm^{-1} to 0.352 μScm^{-1} at Madkot table-5 and figure-26. During second year (2007-08), the values of conductivity fluctuated between 0.076 μScm^{-1} to 0.322 μScm^{-1} at Jauljibi, 0.063 μScm^{-1} to 0.280 μScm^{-1} at Baram and 0.058 μScm^{-1} to 0.263 μScm^{-1} at Madkot table-5 and figure-27. Monthly the highest values of conductivity were recorded in the month of May (0.361 μScm^{-1}, 0.358 μScm^{-1} and 0.352 μScm^{-1}) and the lowest values of conductivity were recorded in the month of January (0.133 μScm^{-1}, 0.139 μScm^{-1} and 0.131 μScm^{-1}) at Jauljibi, Baram and Madkot, respectively during first year table-5 and figure-26. During second year (2007-08), the highest values of conductivity were recorded in the month of July (0.322 μScm^{-1} and 0.263 μScm^{-1}) at Jauljibi and Madkot, respectively and it was in the months of June and July (0.280 μScm^{-1}) at Baram, while the lowest values of conductivity were recorded again in the month of January (0.076 μScm^{-1}, 0.063 μScm^{-1} and 0.058 μScm^{-1}) at Jauljibi, Baram and Madkot, respectively in the study table-5 and figure-27. The highest annual mean values of conductivity were recorded at Jauljibi (0.260 μScm^{-1} and 0.192 μScm^{-1}) and the lowest annual mean values of the parameter were recorded at Madkot (0.250 μScm^{-1} and 0.143 μScm^{-1}) during first year and second year, respectively in the study table-5. During first year (2006-07), the highest seasonal mean values of conductivity were recorded in summer (0.318 μScm^{-1}, 0.315 μScm^{-1} and 0.308 μScm^{-1}), moderate in monsoon (0.267 μScm^{-1}, 0.262 μScm^{-1} and 0.251 μScm^{-1}) and the lowest values of conductivity were recorded in winter (0.194 μScm^{-1}, 0.197 μScm^{-1} and 0.190 μScm^{-1}) at Jauljibi, Baram and Madkot, respectively table-6 and figure-28. During second year (2007-08), the highest values of conductivity were recorded in monsoon (0.284 μScm^{-1}, 0.255v and 0.30 μScm^{-1}), moderate in summer (0.173 μScm^{-1}, 0.163 μScm^{-1} and 0.123 μScm^{-1}) and the lowest value of conductivity were recorded again in winter (0.118 μScm^{-1}, 0.089 μScm^{-1} and 0.075 μScm^{-1}) at Jauljibi, Baram and Madkot, respectively in the study table-6 and figure-29. Altitudinally, the annual mean values of conductivity showed an increasing trend from upstream to downstream, in other words it was observed that increased values of conductivity were recorded to the decreased elevation in the Goriganga river table-5. Statistically, the conductivity showed positive significant correlation with velocity (r=0.5262 and r=0.9272) figures-30, 31 during first year and second year, respectively in the present study.

Table-5
Monthly variations in conductivity at three spots in the Goriganga River during 2006-07 and 2007-08

Months	Conductivity (μScm^{-1})					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	0.273	0.271	0.247	0.322	0.280	0.263
Aug	0.250	0.248	0.232	0.264	0.252	0.242
Sept	0.201	0.188	0.187	0.242	0.210	0.178
Oct	0.273	0.281	0.273	0.182	0.118	0.101
Nov	0.165	0.160	0.150	0.118	0.091	0.078
Dec	0.208	0.209	0.207	0.099	0.084	0.066
Jan	0.133	0.139	0.131	0.076	0.063	0.058
Feb	0.257	0.250	0.244	0.111	0.098	0.074
Mar	0.314	0.312	0.307	0.168	0.148	0.130
Apr	0.341	0.340	0.332	0.185	0.178	0.115
May	0.361	0.358	0.352	0.228	0.230	0.176
Jun	0.344	0.342	0.338	0.311	0.280	0.239
Mean	0.260	0.258	0.250	0.192	0.169	0.143
S.D.	0.071	0.073	0.073	0.082	0.079	0.074

Table-6
Seasonal variations in Conductivity (µScm-^{1}) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Conductivity (µScm-^{1})						
Season	**2006-2007**			**2007-2008**		
	Spot-	**Spot-**	**Spot-**	**Spot-**	**Spot-**	**Spot-**
Monsoon	0.267	0.262	0.251	0.284	0.255	0.230
Winter	0.194	0.197	0.190	0.118	0.089	0.075
Summer	0.318	0.315	0.308	0.173	0.163	0.123

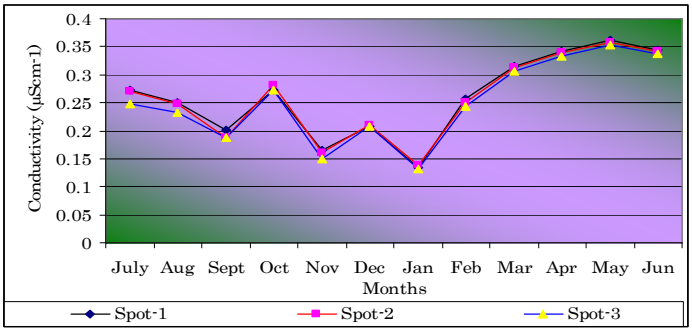

Figure-26
Monthly variations in conductivity at three spots in the Goriganga river during 2006-07

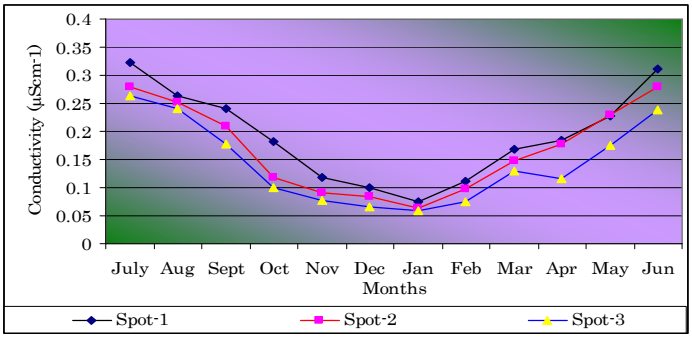

Figure-27
Monthly variations in conductivity at three spots in the Goriganga river during 2007-08

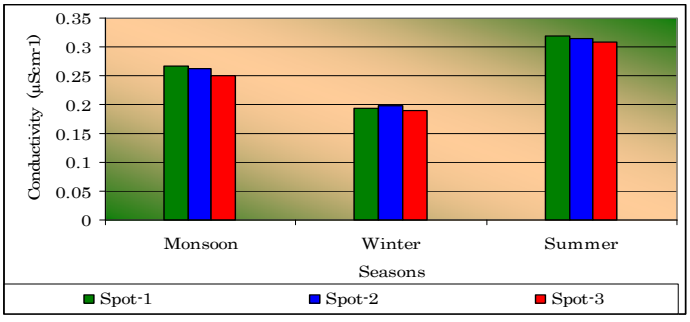

Figure-28
Seasonal variations in conductivity at three spots in the Goriganga river during 2006-07

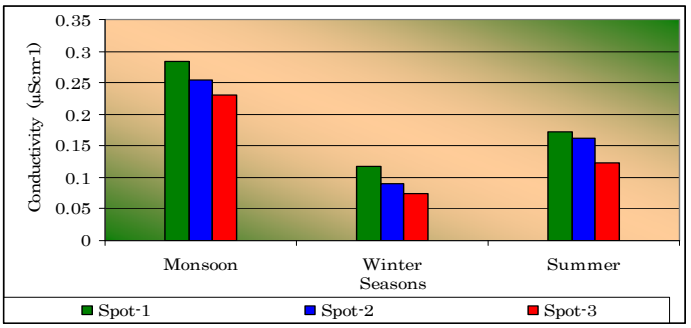

Figure-29
Seasonal variations in conductivity at three spots in the Goriganga river during 2007-08

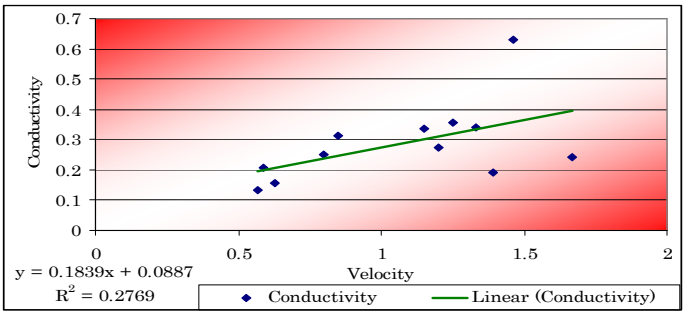

Figure-30
Correlation between conductivity and velocity in the Goriganga river during 2006-07

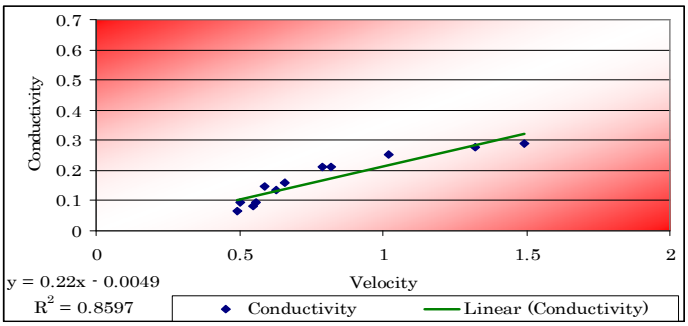

Figure-31
Correlation between conductivity and velocity in the Goriganga river during 2006-07

pH (Hydrogen Ion Concentration): Hydrogen ion concentration expressed in terms of pH depends upon the amount of carbonate and free CO_2 tension in the water. It is an important indicator that shows the acidic or alkaline nature of water. It is therefore, considered as an index of acidic, alkaline and neutral nature of water.

The pH of water of Goriganga river was observed mostly alkaline at all the selected sites throughout the course of study. pH ranged from 7.0 to 8.87 in the first year (2006-07) and from 7.0 to 8.5 in the second year table-7 and figures-32, 33. pH values fluctuated between 7.38 (July) to 8.87 (March) at spot-1 (Jauljibi), 7.16 (June) to 8.61(October) at spot-2 (Baram) and

from 7.0 (September and March) to 8.5 (October, January and April) at spot-3 (Madkot) in the present study during first year table-7 and figure-32. During the subsequent year (2007-08), pH values fluctuated between 7.5 to 8.5 at spot-1 (Jauljibi), 7.0 to 7.5 at spot -2 (Baram) and from 7.0 to 7.5 at spot-3 (Madkot) in the Goriganga river table-7 and figure-33. The minimum values of pH (7.5) were recorded in all the months of the year except November and the maximum (8.5) value of pH was recorded in the month of November at spot-1 (Jauljibi); while spot-2 (Baram) showed the minimum values (7.0) in the months of July, September, October and February and maximum values (7.5) in August, November, December, January, March, April, May and June. At spot-3 (Madkot), the lowest values (7.0) of pH were in the months of July, August, October, February, March and May and the highest values of pH (7.5) were recorded in the months of September, November, December, January and June in the Goriganga river in the present study table 7 and figure-33. Seasonally, the high seasonal mean values of pH (8.41, 8.27 and 8.55) were recorded during the winter season and the low seasonal mean values of pH (7.64, 7.34 and 7.24) were recorded during the rainy season at spot-1, spot-2 and spot-3, respectively during the first year table-8 and figure-34. During second year (2007-08), the high seasonal mean values of pH were recorded as: (7.75) in winter at spot-1, (7.37) in winter and summer equally at spot-2 and (7.5) in monsoon at spot-3, whereas the low seasonal mean values (7.5) in monsoon and summer equally at spot-1, (7.25) in monsoon at spot-2 and (7.05) in summer at spot-3 table-8 and figure-35. The highest annual mean values (8.07 and 7.58) were recorded at spot-1 (Jauljibi), while the lowest (7.70 and 7.22) annual mean values of pH were recorded at spot-3 (Madkot) during 2006-07 and 2007-08, respectively in the Goriganga River. Table-7. The data indicates the alkaline nature of Goriganga river and variations in the mean pH were relatively narrow among the selected sampling spots during the second year (2007-08). Altitudinally, pH increased from upstream to downstream in the present study table 7.

Table-7
Monthly variations in pH at three spots in the Goriganga river during 2006-07 and 2007-08

Months	pH					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	7.38	7.42	7.12	7.5	7.0	7.0
Aug	7.67	7.29	7.5	7.5	7.5	7.0
Sept	7.76	7.5	7.0	7.5	7.0	7.5
Oct	8.8	8.61	8.5	7.5	7.0	7.0
Nov	8.14	8.39	7.5	8.5	7.5	7.5
Dec	8.29	8.04	7.72	7.5	7.5	7.5
Jan	8.43	8.15	8.5	7.5	7.5	7.5
Feb	7.82	7.5	8.0	7.5	7.0	7.0
Mar	8.87	7.36	7.0	7.5	7.5	7.0
Apr	8.12	7.72	8.5	7.5	7.5	7.21
May	7.90	7.89	7.79	7.5	7.5	7.0
Jun	7.76	7.16	7.36	7.5	7.5	7.5
Mean	8.07	7.75	7.70	7.58	7.33	7.22
S.D.	0.454	0.463	0.566	0.288	0.246	0.249

Table-8
Seasonal variations in pH of water at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	pH of water					
	2006-2007			2007-2008		
	Spot-1	Spot-2	Spot-3	Spot-1	Spot-2	Spot-3
Monsoon	7.64	7.34	7.24	7.5	7.25	7.5
Winter	8.41	8.27	8.55	7.75	7.37	7.37
Summer	8.17	7.61	7.82	7.5	7.37	7.05

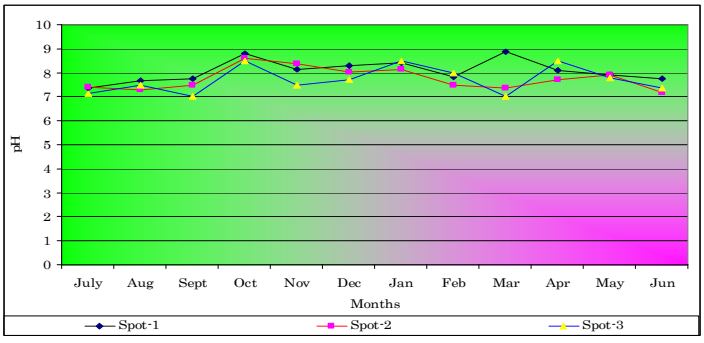

Figure-32
Monthly variations in pH at three spots in the Goriganga river during 2006-07

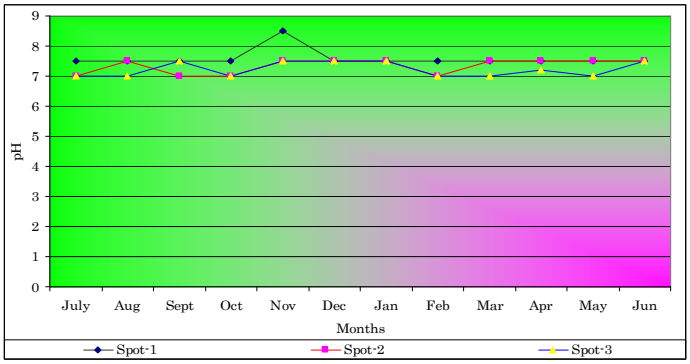

Figure-32
Monthly variations in pH at three spots in the Goriganga river during 2007-08

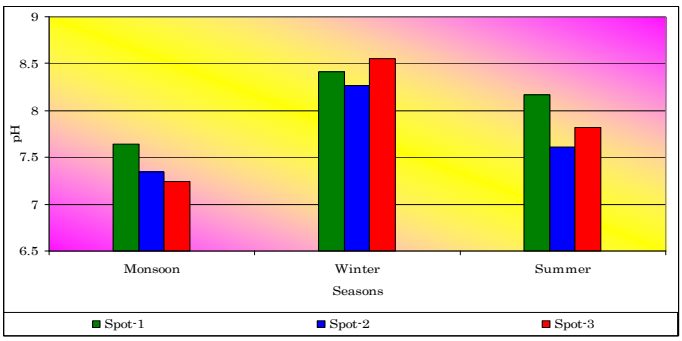

Figure-34
4.58 Seasonal variations in pH at three spots in the Goriganga river during 2006-07

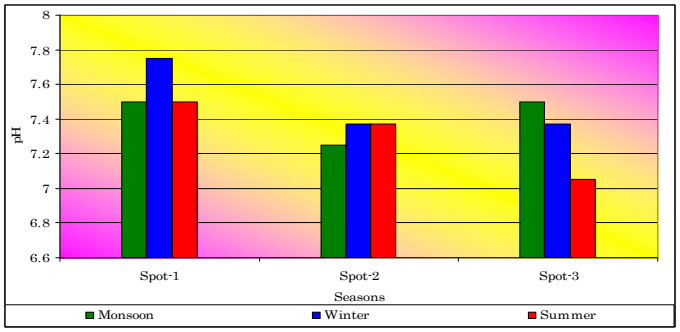

Figure-35
4.58 Seasonal variations in pH at three spots in the Goriganga river during 2007-08

Alkalinity: The values of alkalinity ranged from 62 mg/l to 190 mg/l in the first year and from 84 mg/l to 180 mg/l in the second year table-9 and figures-36, 37. During first year (2006-07), the maximum values of alkalinity (170 mg/l, 190 mg/l and 190 mg/l) were recorded in the month of January at spot-1, spot-2 and spot-3, respectively and the lowest values of alkalinity (64 mg/l and 62 mg/l) were recorded in the month of July at spot- 1 and spot-2, whereas it was in the month of August (82 mg/l) at spot-3 (table 4.5 and figures- 4.72). During second year (2007-08), the maximum value of alkalinity (170 mg/l) was recorded again in the month of January at spot-1, in January and March (148 mg/l) at spot-2 and in February (180 mg/l) at spot-3, while the lowest values of alkalinity (84 mg/l and 92 mg/l) were again recorded in the month of July at spot-1 and spot-3 while it was in the month of June (90 mg/l) at spot-2 in the present study table-9 and figure-37. Like other physico-chemical variables, alkalinity also showed monthly, seasonally, yearly and altitudinal variations in the present study tables-9, 10 and figures-36, 37, 38, 39. The highest seasonal mean values of alkalinity (148.5 mg/l, 157.5 mg/l and 157 mg/l) and (141 mg/l, 149 mg/l and 146 mg/l) were recorded in the winter season and the lowest seasonal mean values (96.25 mg/l, 100 mg/l and 99 mg/l) and (107.5 mg/l, 114 mg/l and 108 mg/l) were in the monsoon season at spot-1, spot-2 and spot-3 during first and second year, respectively in the study table-10 and figures-38, 39. On the yearly basis, the highest annual mean values of alkalinity (132.16 mg/l and 132.33 mg/l) were recorded at spot-3 (Madkot), while the lowest annual mean values of alkalinity (125.08 mg/l, 125.66 mg/l) were recorded at spot-1 (Jauljibi) in the first year (2006-07) and in the second year (2007-08), respectively in the present study table-9. Altitudinally, the annual mean values of alkalinity show an increasing trend from downstream to upstream (125.08 mg/l, 129.5 mg/l and 132.16 mg/l) in the first year and (125.66 mg/l, 128.16 mg/l and 132.33 mg/l) in the second year table-9. The annual mean values of alkalinity were slightly higher in second year than the first year in the study table-9. The alkalinity of water showed positive significant correlation with pH (r = 0.525275) in the first year figure-40 and nonsignificant (r = 0.173179) in the second year figure-41.

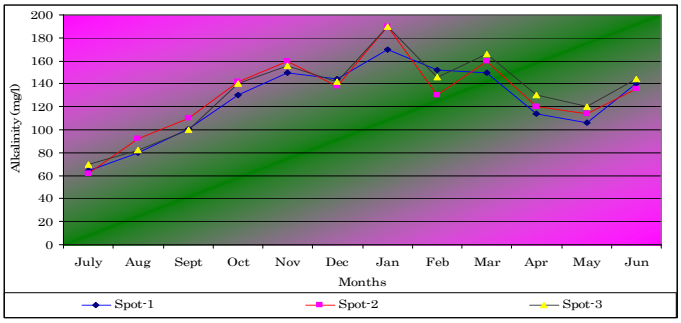

Figure-36
Monthly variations in alkalinity at three spots in the Goriganga river during 2006-07

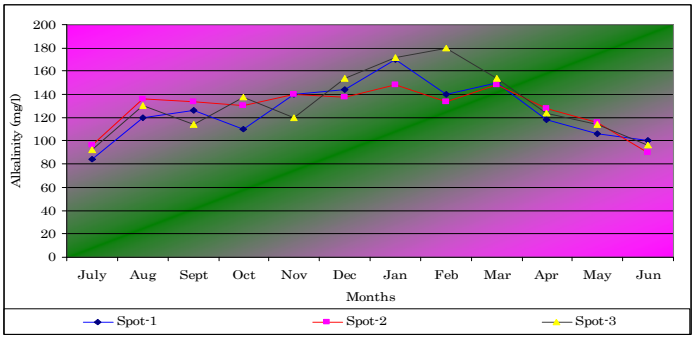

Figure-37
Monthly variations in alkalinity at three spots in the Goriganga river during 2007-08

Table-9
Monthly variations in alkalinity at three spots in the Goriganga river during 2006-07 and 2007-08

Month Months	Alkalinity (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	64	62	70	84	96	92
Aug	80	92	82	120	136	130
Sept	101	110	100	126	134	114
Oct	130	142	140	110	130	138
Nov	150	160	156	140	140	120
Dec	144	138	142	144	138	154
Jan	170	190	190	170	148	172
Feb	152	130	146	140	134	180
Mar	150	160	166	150	148	154
Apr	114	120	130	118	128	124
May	106	114	120	106	116	114
Jun	140	136	144	100	90	96
Mean	125.08	129.5	132.16	125.66	128.16	132.33
S.D.	32.219	33.662	34.530	24.163	18.575	28.062

Table-10
Seasonal variations in Alkalinity (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	Alkalinity (mg/l)					
	2006-2007			2007-2008		
	Spot-	Spot-	Spot-	Spot-	Spot-	Spot-
Monsoon	96.25	100	99	107.5	114	108
Winter	148.5	157.5	157	141	149	146
Summer	130.5	131	140.5	128.5	131.5	143

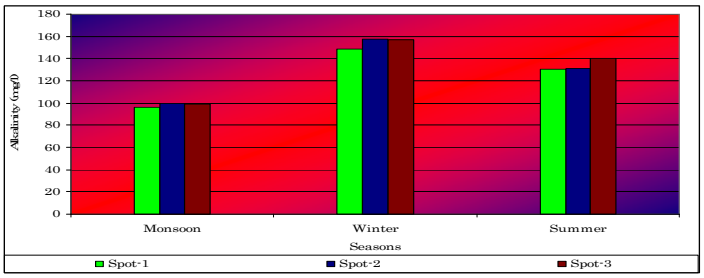

Figure-38
Seasonal variations in alkalinity at three spots in the Goriganga river during 2006-07

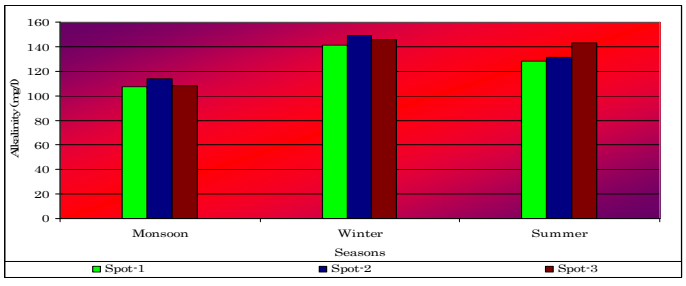

Figure-39
Seasonal variations in alkalinity at three spots in the Goriganga river during 2007-09

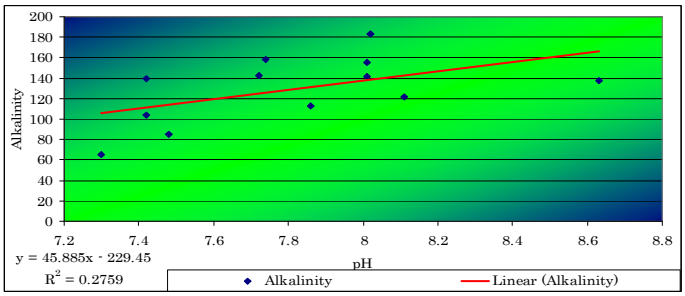

Figure-40
Correlation between alkalinity and pH in the Goriganga river during 2006-07

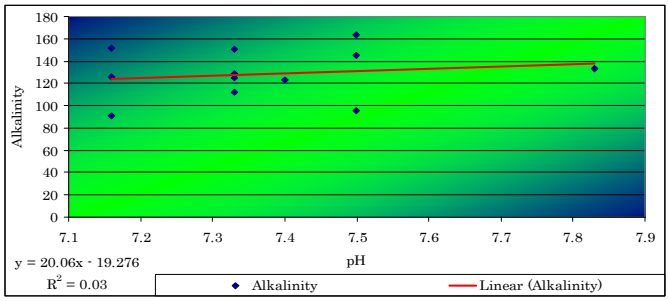

Figure-41
Correlation between alkalinity and pH in the Goriganga river during 2007-08

Carbonate And Bicarbonate: Carbonates at all the spots (Jauljibi, Baram and Madkot) in the Goriganga river remained below the detection limit or mostly absent except few months (December, January, February and March) at spot-1, (December, January and March) at spot-2 and (December, January, February, March and April) at spot-3 during 2006-07 and (November and January) at spot-1, (November, January and February) at spot-2 and (October, November, December, January, February, March and April) at spot-3 during 207-08

table-11. Therefore, no clear cut pattern was discernible for the parameter.

Bicarbonate was present throughout the study period at all the spots in the Goriganga river. The bicarbonate ranged from 62.00 mg/l to 180.00 mg/l in the first year (2006-07) and 84.00 mg/l to 170.00 mg/l in the second year table-12. The bicarbonate concentration in the Goriganga river has been fluctuated between 64.00 mg/l to 162.00 mg/l at spot-1, 62.00 mg/l to 180.00 mg/l at spot-2 and 70.00 mg/l to 180.00 mg/l at spot-3 in the first year table-12. The highest values of bicarbonate (162.00 mg/l, 180.00 mg/l and 180.00 mg/l) were recorded in the month of January and the lowest values (64.00 mg/l, 62.00 mg/l and 70.00 mg/l) of bicarbonate were observed in the month of July at spot-1, spot-2 and spot-3, respectively in the first year table-12 and figure-42. In the second year (2007-08), it was fluctuated between 84.00 mg/l to 162.00 mg/l at spot-1, 90.00 mg/l to 148.00 mg/l at spot-2 and 92.00 mg/l to 170.00 mg/l at spot-3 in the present study table-12 and figure-43. The highest values of bicarbonate (162.00 mg/l) were recorded in the month of January at spot-1, (148.00 mg/l) in the month of March at spot-2 and 170.00 (mg/l) in the month of February at spot-3 and the lowest values (84.00 mg/l and 92.00 mg/l) were recorded at spot-1 and spot-3 in the month of July, whereas it was (90.00 mg/l) at spot-2 in the month of June in the present study table-12 and figure-43. The highest seasonal mean values (145.00 mg/l, 153.5 mg/l and 153.00 mg/l) and (137.5 mg/l, 135.00 mg/l and 139.5 mg/l) were recorded in winter and the lowest seasonal mean values (96.25 mg/l, 100.00 mg/l and 99.00 mg/l) and (107.5 mg/l, 114.00 mg/l and 108.00 mg/l) of bicarbonate were recorded during monsoon at spot-1, spot-2 and spot-3 during first year (2006-07) and second year (2007-08), respectively table-14 and figures-44, 45. The highest annual mean was recorded as (129.5 mg/l) during 2006-07 and (128.5 mg/l) during 2007-08 at spot-3, while the lowest annual mean was recorded as (123.25 mg/l) in the first year and (124.5 mg/l) in the second year at spot-1 in the Goriganga river table-12. Altitudinally, bicarbonate concentration decreases from upstream to downstream (123 mg/l, 127.5 mg/l and 129.5 mg/l) in the first year (2006-07) and (124.5 mg/l, 126.5 mg/l and 128.5 mg/l) in the second year table-12.

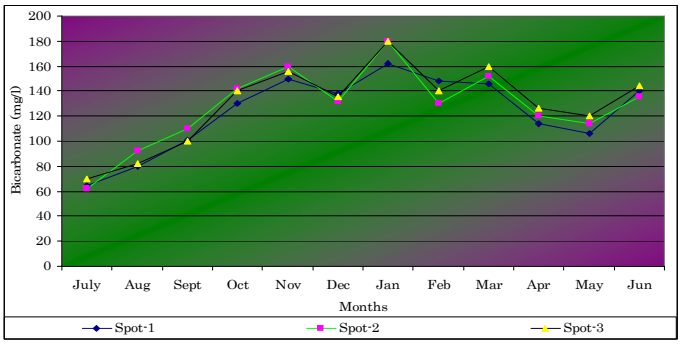

Figure-42
Monthly variations in bicarbonate at three spots in the Goriganga river during 2006-07

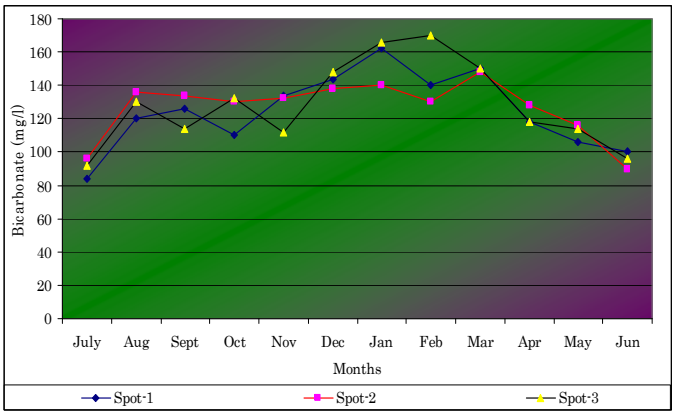

Figure-43
Monthly variations in bicarbonate at three spots in the Goriganga river during 2007-08

Table-11
Monthly variations in Carbonate at three spots in the Goriganga river during 2006-07 and 2007-08

Month Months	Carbonate (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	nd	nd	nd	nd	nd	nd
Aug	nd	nd	nd	nd	nd	nd
Sept	nd	nd	nd	nd	nd	nd
Oct	nd	nd	nd	nd	nd	3.00
Nov	nd	nd	nd	3.00	4.00	4.00
Dec	3.00	3.00	3.00	nd	0.00	3.00
Jan	4.00	5.00	5.00	4.00	4.00	3.00
Feb	2.00	nd	3.00	nd	2.00	5.00
Mar	2.00	4.00	3.00	nd	nd	2.00
Apr	nd	nd	2.00	nd	nd	3.00
May	nd	nd	nd	nd	nd	nd
Jun	nd	nd	nd	nd	nd	nd
Mean	0.91	1.00	1.33	0.58	0.83	1.91
S.D.	1.483	1.921	1.809	1.433	1.640	1.814

Table-12
Monthly variations in Bicarbonate at three spots in the Goriganga river during 2006-07 and 2007-08

Month Months	Bicarbonate (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	64	62	70	84	96	92
Aug	80	92	82	120	136	130
Sept	101	110	100	126	134	114
Oct	130	142	140	110	130	132
Nov	150	160	156	134	132	112
Dec	138	132	136	144	138	148
Jan	162	180	180	162	140	166
Feb	148	130	140	140	130	170
Mar	146	152	160	150	148	150
Apr	114	120	126	118	128	118
May	106	114	120	106	116	114
Jun	140	136	144	100	90	96
Mean	123.25	127.5	129.5	124.5	126.5	128.5
S.D.	30.376	31.358	32.227	22.613	17.459	25.543

Table-13
Seasonal variations in Carbonate (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	Carbonate (mg/l)					
	2006-2007			2007-2008		
	Spot-1	Spot-2	Spot-3	Spot-1	Spot-2	Spot-3
Monsoon	0.00	0.00	0.00	0.00	0.00	0.00
Winter	1.75	2.00	2.00	1.75	2.00	3.25
Summer	1.00	1.00	2.00	0.00	0.5	2.5

Table-14
Seasonal variations in Bicarbonate (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08.

Season	BiCarbonate (mg/l)					
	2006-2007			2007-2008		
	Spot-1	Spot-2	Spot-3	Spot-1	Spot-2	Spot-3
Monsoon	96.25	100.00	99.00	107.5	114.00	108.00
Winter	145.00	153.5	153.00	137.5	135.00	139.5
Summer	128.5	129.00	136.5	128.5	130.5	138.00

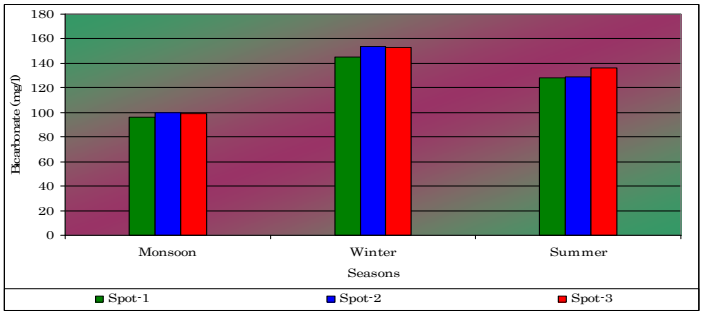

Figure-44
Seasonal variations in bicarbonate at three spots in the Goriganga river during 2006-07

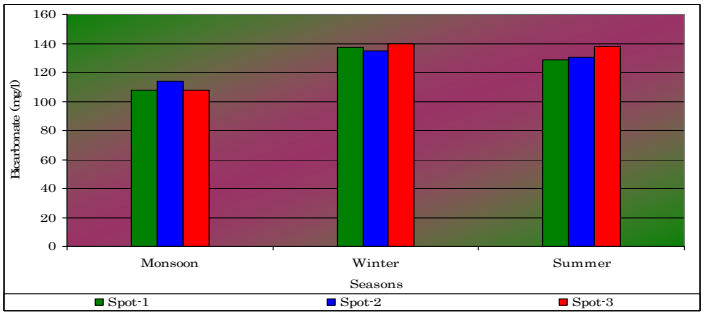

Figure-45
Seasonal variations in bicarbonate at three spots in the Goriganga river during 2007-08

Free CO_2: Free CO_2 ranged from zero or absent to 6.0 mg/l during both the investigating years (2006-07 and 2007-08). Free CO_2 values fluctuated between zero or absent to 6.0 mg/l at spot-1 (Jauljibi) and spot-2 (Baram) while it fluctuated from zero or absent to 4.0 mg/lat spot-3 (Madkot) in the Goriganga river during first year, 2006-07 table-15 and figure-46. The lowest or absent free CO_2 was recorded in the months of December, January, February and March while the highest value (6.0 mg/l) of free CO_2 was recorded in the month of October at spot-1 (Jauljibi); the lowest or absent free CO_2 was recorded in the months of December, January and March, while the highest value (6.0 mg/l) were recorded in the months of September and May at spot -2 (Baram) and at spot-3 (Madkot), the lowest value or absent free CO_2 was recorded in the months of December, January, February, March and April while the highest values (4.0 mg/l) were recorded in the months of September and May during first year in the study table-15 and figure-46. During the subsequent year (2007-08), free CO_2 values fluctuated between zero or absent to 6.0 mg/l at spot-1 (Jauljibi) and spot -2 (Baram) while it fluctuated between zero or absent to 4.0 mg/l at spot-3 (Madkot) in the Goriganga river table 15 and figure-

47. The minimum or absent free CO_2 was recorded in the months of November and January while the maximum value (6.o mg/l) was recorded in the month of September at spot-1 (Jauljibi); the minimum or absent free CO_2 was recorded in the months of November, January and February at spot-2 (Baram) and at spot-3 (Madkot), the minimum or absent values were recorded in the months of October to April and the maximum value (4.0 mg/l) was recorded in the months of August and June in the Goriganga river in the present study table-15 and figure-47.

The maximum seasonal mean values of free CO_2 were recorded during the rainy season (3.05 mg/l, 3.0 mg/l and 2.05 mg/l) and (4.05 mg/l, 3.05 mg/l and 3.0 mg/l), while the minimum seasonal values of free CO2 were recorded in the summer season (2.0 mg/l, 1.05 mg/l and 1.0 mg/l) and (2.0 mg/l, 2.0 mg/l and 0.0 mg/l) at spot-1, spot-2 and spot-3 during first year and second year (2006-07 and 2007-08), respectively in the study table 16 and figures-48, 49.

The highest annual mean values of the free CO_2 (2.66 mg/l and 3.0 mg/l) were recorded at spot-1 (Jauljibi), while the lowest annual mean values (1.5 mg/l and 1.16 mg/l) of free CO_2 were recorded at spot-3 (Madkot) during 2006-07 and 2007-08, respectively in the Goriganga river Table 15. On the basis of present data it was observed that higher concentration of free CO_2 was observed in the study of first year (2006-07) as compared to the second year (2007-08) in the study table-15 and figures-46, 47. The values of free CO_2 decreased from downstream to upstream in the Goriganga river (2.66 mg/l, 2.33 mg/l and 1.5 mg/) during first year (2006-07) and (3.0 mg/l, 2.5 mg/l and 1.16 mg/l) in the second year (2007-08) in the present study table 15.

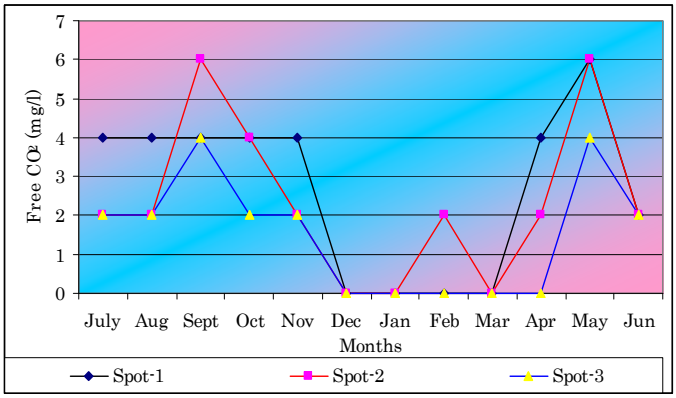

Figure-46
Monthly variations in free CO_2 at three spots in the Goriganga river during 2006-07

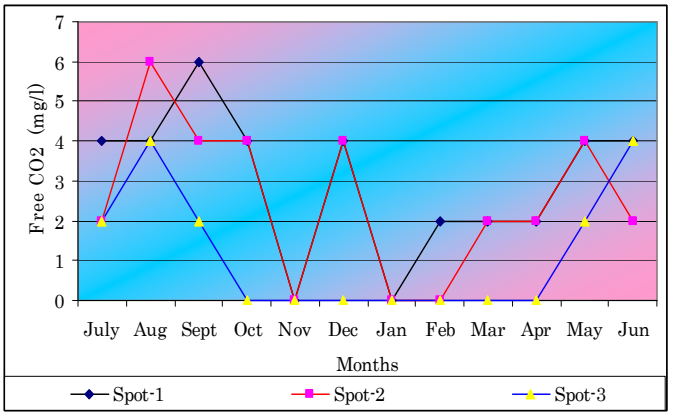

Figure-47
Monthly variations in free CO_2 at three spots in the Goriganga river during 2007-08

Table-15
Monthly variations in free co_2 at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Free CO_2 (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	4.0	2.0	2.0	4.0	2.0	2.0
Aug	4.0	2.0	2.0	4.0	6.0	4.0
Sept	4.0	6.0	4.0	6.0	4.0	2.0
Oct	4.0	4.0	2.0	4.0	4.0	Absent
Nov	4.0	2.0	2.0	Absent	Absent	Absent
Dec	Absent	Absent	Absent	4.0	4.0	Absent
Jan	Absent	Absent	Absent	Absent	Absent	Absent
Feb	Absent	2.0	Absent	2.0	Absent	Absent
Mar	Absent	Absent	Absent	2.0	2.0	Absent
Apr	4.0	2.0	Absent	2.0	2.0	Absent
May	6.0	6.0	4.0	4.0	4.0	2.0
Jun	2.0	2.0	2.0	4.0	2.0	4.0
Mean	2.66	2.33	1.5	3.0	2.5	1.16
S.D.	2.146	2.059	1.507	1.809	1.930	1.585

Table-16
Seasonal variations in Free CO_2 (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	Free CO_2 (mg/l)					
	2006-2007			2007-2008		
	Spot-	Spot-	Spot-	Spot-	Spot-	Spot-
Monsoon	3.05	3.0	2.05	4.05	3.05	3.0
Winter	2.0	1.05	1.0	2.0	2.0	0.0
Summer	2.05	2.05	1.0	2.05	2.0	0.5

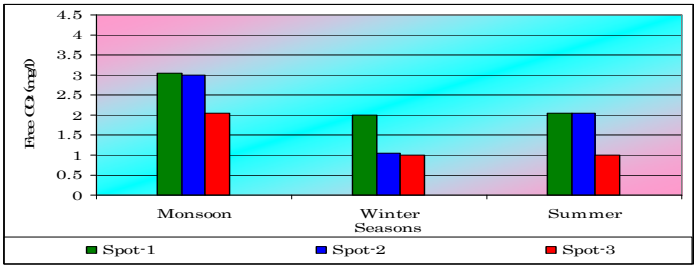

Figure-48
Seasonal variations in free CO_2 at three spots in the Goriganga river during 2006-07

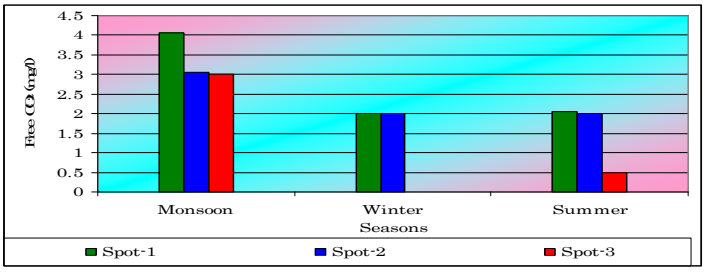

Figure-49
Seasonal variations in free CO_2 at three spots in the Goriganga river during 2007-08

Dissolved Oxygen (D.O): Dissolved oxygen is the most important factor that supports aquatic life and self purification capacity of water body in the high altitude rivers. Dissolved oxygen is the most important gas produced during photosynthesis by plankton and higher aquatic plants in an aquatic environment. It is thus, considered as an index functioning of biological and physical processes. The dissolved oxygen ranged from 5.6 mg/l to 12.0 mg/l in the first year and from 6.4 mg/l to 16.8 mg/l in the second year in the present study table-17 and figures-50, 51. The concentration of dissolved oxygen has shown substantial variations in Goriganga river fluctuated between 5.6 mg/l to 11.6 mg/l, 7.2 mg/l to 10.8 mg/l and 6.0 to 12.0 mg/l at spot-1 (Jauljibi), spot-2 (Baram) and spot-3 (Madkot), respectively, during first year table-17 and figure-50. While it has been fluctuated between 8.0mg/l to 16.8 mg/l, 6.4 mg/l to 16.0 mg/l and 9.6 mg/l to 16.8 mg/l at spot-1 (Jauljibi), spot-2 (Baram) and spot-3 (Madkot) respectively, during second year table-17 and figure-51. Monthly maximum values of dissolved oxygen were recorded in the month of January (11.6 mg/l, 10.8 mg/l and 12.0 mg/l) at spot-1 (Jauljibi), spot-2 (Baram) and spot-3 (Madkot), respectively and the minimum values were recorded in the month of September, (5.6 mg/l and 7.2 mg/l) at spot-1 (Jauljibi) and spot-2 (Baram), respectively, while it was minimum in the month of June (6.0 mg/l) at spot-3 (Madkot) during 2006-07 table-17 and figure-50. During second year (2007-08), monthly maximum values of dissolved oxygen were recorded in the month of December (16.8 mg/l) at spot-1 (Jauljibi), and in January (16.0 mg/l and 16.8 mg/l) at spot-2 (Baram) and spot-3 (Madkot), respectively, and the minimum values were recorded in the month of July (8.0 mg/l, 6.4 mg/l and 9.6 mg/l) at spot-1 (Jauljibi), spot-2 (Baram) and spot-3 (Madkot), respectively table-17 and figure-51. Seasonally, low values of dissolved oxygen (6.8 mg/l, 7.5 mg/l and 6.85 mg/l) and (8.9 mg/l, 9.2 mg/l and 10.2 mg/l) were recorded during the monsoon and high values (9.7 mg/l, 9.4 mg/l and 10.9 mg/l) and (13.6 mg/l, 13.7 mg/l and 14.9 mg/l) were recorded during the winter season at spot-1, spot-2 and spot-3 during first and second year, respectively in the study table-18 and figures-52, 53. The highest annual mean values were recorded at spot-3 (9.31 mg/l and 12.83 mg/l), while the lowest annual mean values were recorded at spot-1 (8.36 mg/l and 11.03 mg/l) during 2006-07 and 2007-08, respectively table-17. On the yearly basis, second year (2007-08) recorded more dissolved oxygen content than the previous year table-17 and figures- 50, 51. In the study, altitudinally dissolved oxygen values (annual mean values) decrease from upstream to downstream in the Goriganga river (9.31 mg/l, 8.73 mg/l and 8.36 mg/l) at spot-3, spot-2 and spot-1, respectively in the year 2006-07, and (12.83 mg/l, 11.43 mg/l and 11.03 mg/l) at spot-3, spot-2 and spot-1, respectively in the year 2007-08 table-17.

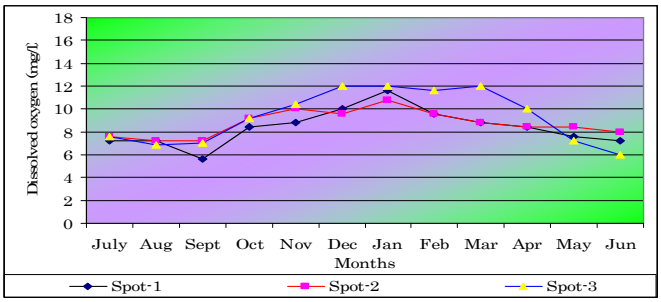

Figure-50
Monthly variations in total dissolved oxygen (D.O) at three spots in the Goriganga river during 2006-07

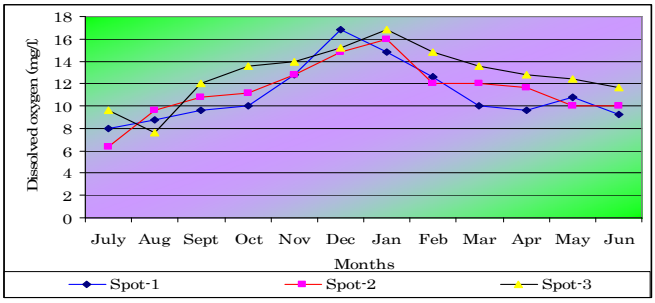

Figure-51
Monthly variations in total dissolved oxygen (D.O) at three spots in the Goriganga river during 2007-08

Table-17
Monthly variations in dissolved oxygen (D.O) at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Dissolved oxygen (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	7.2	7.6	7.6	8.0	6.4	9.6
Aug	7.2	7.2	6.8	8.8	9.6	7.6
Sept	5.6	7.2	7.0	9.6	10.8	12.0
Oct	8.4	9.2	9.2	10.0	11.2	13.6
Nov	8.8	10.0	10.4	12.8	12.8	14.0
Dec	10.0	9.6	12.0	16.8	14.8	15.2
Jan	11.6	10.8	12.0	14.8	16.0	16.8
Feb	9.6	9.6	11.6	12.6	12.0	14.8
Mar	8.8	8.8	12.0	10.0	12.0	13.6
Apr	8.4	8.4	10.0	9.6	11.6	12.8
May	7.6	8.4	7.2	10.8	10.0	12.4
Jun	7.2	8.0	6.0	9.2	10.0	11.6
Mean	8.36	8.73	9.31	11.03	11.43	12.83
S.D.	1.576	1.142	2.308	2.642	2.486	2.486

Table-18
Seasonal variations in Dissolved oxygen (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	Dissolved oxygen (mg/l)					
	2006-2007			2007-2008		
	Spot-1	Spot-2	Spot-3	Spot-1	Spot-2	Spot-3
Monsoon	6.8	7.5	6.85	8.9	9.2	10.2
Winter	9.7	9.4	10.9	13.6	13.7	14.9
Summer	8.6	8.54	10.2	10.75	11.4	13.4

Velocity: The velocity of Goriganga river ranged from 0.52 m/sec. to 1.72 m/sec. in the year 2006-07 and from 0.47 m/sec. to 1.61 m/sec. in the year 2007-08. The values of velocity of Goriganga river vary monthly, seasonally, yearly and spot-wise Tables 19, 20 and figures 54, 55, 56, 57. Monthly values of velocity of water of Goriganga river fluctuated between 0.52 m/sec.(January) to 1.67m/sec. (August) at spot-1; from 0.58 m/sec.(January) to 1.72 m/sec. (August) at spot-2 and from 0.60 m/sec.(December) to 1.63 m/sec. (August) at spot-3 during first year (July-2006 to June-2007) table 19 and Fig 54, while it fluctuated between 0.47 m/sec. (February) to 1.49 m/sec.(July) at spot-1, from 0.50 m/sec. (January) to 1.61 m/sec.(July) at spot-2 and from 0.49 m/sec. (February) to 1.38 m/sec.(July) at spot-3 during second year (from July-2007 to June-2008) Table 19 and figure-55. The velocity increased from February (0.83 m/sec., 0.83 m/sec.) to onwards and reached at the maximum in August (1.67 m/sec., 1.72 m/sec) at spot-1 and spot-2, respectively during 2006-07, while it increased from January (0.62 m/sec.) and reached at its peak in August (1.63 m/sec.) at spot-3 during the same year table-19 and figure-55. While during the second year (from July-2007 to June-2008), the values of velocity of water increased from March (0.50 m/sec. at spot-1), from February (0.56 m/sec. at spot-2) and from March (0.61 m/sec. at spot-3) and reached at maximum in July (1.49 m/sec. at spot-1;1.61 m/sec. at spot-2 and 1.38 m/sec. at spot-3) table-19 and figure-55.

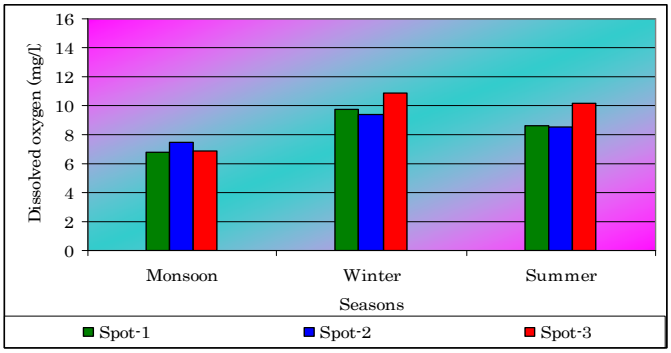

Figure-52
Seasonal variations in total dissolved oxygen (D.O) at three spots in the Goriganga river during 2006-07

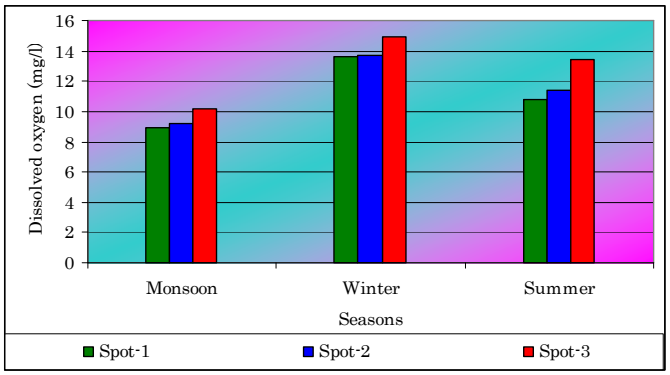

Figure-53
Seasonal variations in total dissolved oxygen (D.O) at three spots in the Goriganga river during 2007-08

The highest values of velocity of water was in the month of August (1.67 m/sec. at spot-1; 1.72 m./sec. at spot-2 and 1.63 m/sec at spot-3) during first year table-19 and figure-54, while it was in the month of July (1.49 m/sec. at spot-1; 1.61 m/sec. at spot-2 and 1.38 m/sec. at spot-3) during second year (2007-08) table-19 and figure-55. Generally, the highest seasonal mean values of velocity of water at all selected sites were recorded, during rainy season followed by summer and minimum seasonal mean values were recorded in winter season during both the years, 2006-07 and 2007-08 table-20 and figures-56, 57. The annual mean values of velocity of water were higher during first year (1.04 m/sec., 1.14 m/sec. and 1.05 m/sec.) at spot-1, spots-2 and spots-3, respectively table 19 and figures-54, 55 as compared to the second year (0.76 m/sec., 0.85 m/sec. and 0.74 m/sec.) at spot-1, spot-2 and spots-3, respectively table-19 and figures 4.38, 4.39). During the entire course of the study it was observed that the velocity was higher at spot-2 than the rest of the two spots because of the higher gradients, in other words, the velocity of water of Goriganga river was the highest at spot-2 (Baram) in comparison to the river current at spot-3 (Madkot) and spot-1 (Jauljibi) due to the gradual increase in slope and decrease in latitude from Madkot to Jauljibi and changing phase of the geography of the river bed. It was also observed that high velocity during summer months might be because of melting of snow at the origin of the river.

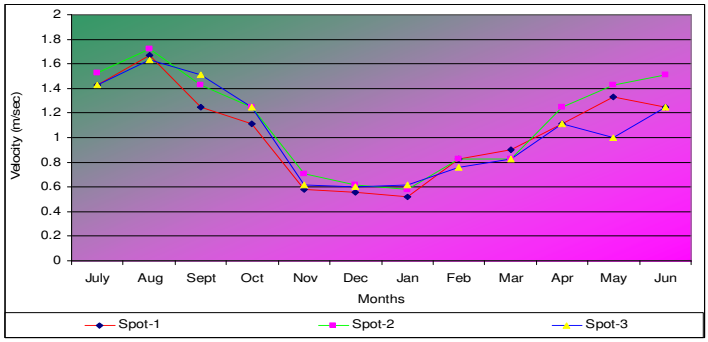

Figure-54
Monthly variations in velocity at three spots in the Goriganga river during 2006-07

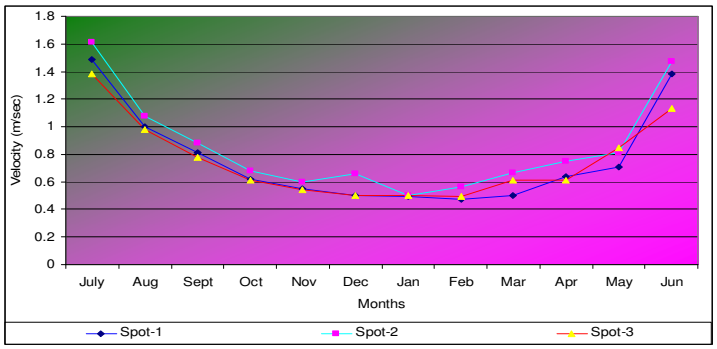

Figure-55
Monthly variations in velocity at three spots in the Goriganga river during 2007-08

Table-19
Monthly variations in velocity of water at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Velocity (m/sec)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	1.43	1.53	1.43	1.49	1.61	1.38
Aug	1.67	1.72	1.63	1.0	1.08	0.98
Sept	1.25	1.43	1.51	0.81	0.88	0.78
Oct	1.11	1.25	1.25	0.62	0.68	0.61
Nov	0.58	0.71	0.62	0.55	0.60	0.54
Dec	0.56	0.62	0.60	0.50	0.66	0.50
Jan	0.52	0.58	0.62	0.49	0.50	0.50
Feb	0.83	0.83	0.76	0.47	0.56	0.49
Mar	0.90	0.83	0.83	0.50	0.67	0.61
Apr	1.11	1.25	1.11	0.64	0.75	0.61
May	1.33	1.43	1.00	0.71	0.81	0.85
Jun	1.25	1.51	1.25	1.38	1.47	1.13
Mean	1.04	1.14	1.05	0.76	0.85	0.74
S.D.	0.370	0.402	0.367	0.350	0.355	0.261

Table-20
Seasonal variations in Velocity of water (m/sec) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Season	Velocity of water (m/sec)					
	2006-2007			2007-2008		
	Spot-	Spot-	Spot-	Spot-	Spot-	Spot-
Monsoon	1.40	1.56	1.45	1.17	1.26	1.06
Winter	0.69	0.79	0.77	0.54	0.61	0.53
Summer	1.04	1.08	0.92	0.58	0.69	0.64

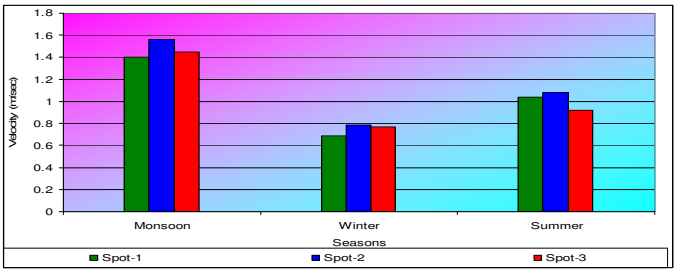

Figure-56
Seasonal variations in velocity at three spots in the Goriganga river during 2006-07

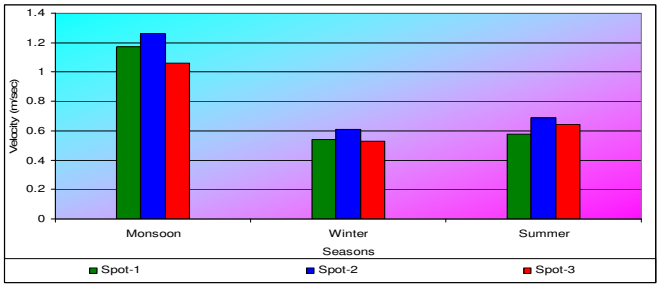

Figure-57
Seasonal variations in velocity at three spots in the Goriganga river during 2007-08

Acidity: The values of acidity ranged from 5.0 mg/l to 30.0 mg/l in the first year and from 5.0 mg/l to 40.0 mg/l in the second year in the present study table-21. The values of acidity fluctuated between 7.5 mg/l (January) to 30.0 mg/l (August) at Jauljibi, 5.0 mg/l (February) to 30.0 mg/l (August) at Baram and 5.0 mg/l (February) to 22.5 mg/l (July) at Madkot during first year (2006-07), while it fluctuated between 7.5 mg/l (December) to 40.0 mg/l (July and August) at Jauljibi, 7.5 mg/l (November) to 35.0 mg/l (June and July) at Baram and 5.0 mg/l (November) to 30.0 mg/l (July) at Madkot during second year table-21 and figures-58, 59.

In general, the acidity content of water at different spots in the Goriganga river was observed to be influenced by the seasons of the year and a rising trend was noticed from summer and reached peak during monsoon season in the present study table-22 and figures-60, 61. It was observed that the values of acidity were low (18.12 mg/l and 10.62 mg/l) at Jauljibi and Baram during the winter season, whereas at Baram (spot-2) the low values (13.75 mg/l) of acidity were recorded in summer season and the high values of acidity (23.67 mg/l, 23.05 mg/l and 19.37 mg/l) were recorded in monsoon season during first year, table-22 and figure-60. During second year (2007-08), the low values of acidity (13.75 mg/l, 12.5 mg/l and 9.37 mg/l) were recorded in winter season and the high values of acidity (30.62 mg/l, 26.87 mg/l and 20.0 mg/l) were recorded in monsoon season table-22 and figure-61. On the yearly basis, the highest annual mean values (19.9 mg/l and 19.29 mg/l) were recorded at Jauljibi (spot-1) and the lowest annual mean values (14.14 mg/l and 14.16 mg/l) were recorded at Madkot during first year (2006-07) and second year (2007-08), respectively in the present study table-21. It has been observed that acidity increases from upstream to downstream during the years, 2006-07 and 2007-08.

Table-21
Monthly variations in acidity at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Acidity (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	25.0	25.0	22.5	40.0	30.0	30.0
Aug	30.0	30.0	20.0	40.0	25.0	17.5
Sept	17.2	17.2	15.0	17.5	17.5	12.5
Oct	22.5	25.0	10.0	15.0	22.5	15.0
Nov	20.0	20.0	12.5	22.5	7.5	5.0
Dec	22.5	20.0	10.0	7.5	10.0	10.0
Jan	7.5	12.5	10.0	10.0	10.0	7.5
Feb	15.0	5.0	5.0	15.0	12.5	12.5
Mar	22.5	20.0	17.2	12.5	10.0	7.5
Apr	15.0	15.0	12.5	10.0	12.5	15.0
May	20.0	15.0	15.0	17.5	20.0	17.5
Jun	22.5	20.0	20.0	25.0	35.0	20.0
Mean	19.9	18.72	14.14	19.29	17.70	14.16
S.D.	5.753	6.533	5.132	11.256	8.884	6.770

Table-22
Seasonal variations in Acidity (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Acidity (mg/l)						
Season	**2006-2007**			**2007-2008**		
	Spot-	**Spot-**	**Spot-**	**Spot-**	**Spot-**	**Spot-**
Monsoon	23.67	23.05	19.37	30.62	26.87	20.0
Winter	18.12	19.37	10.62	13.75	12.5	9.37
Summer	18.12	13.75	12.42	13.75	13.75	13.12

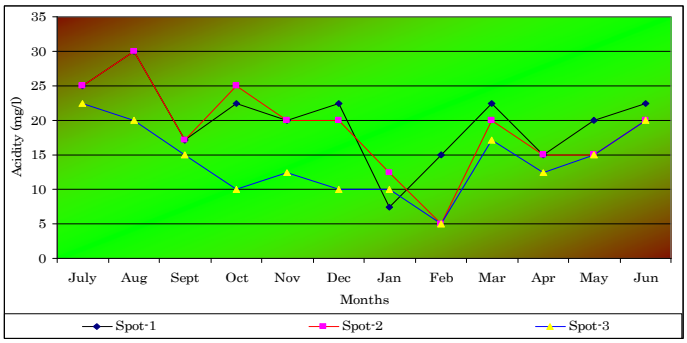

Figure-58
Monthly variations in acidity at three spots in the Goriganga river during 2006-07

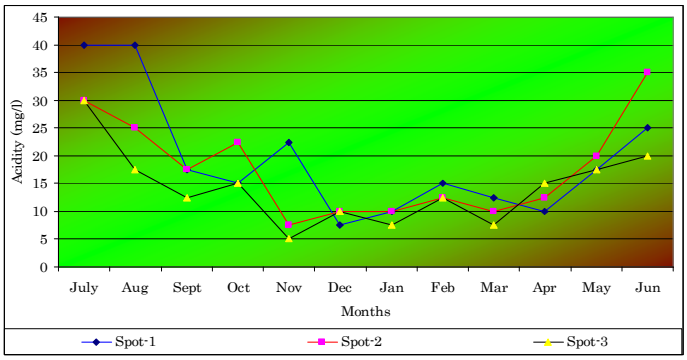

Figure-59
Monthly variations in acidity at three spots in the Goriganga river during 2007-08

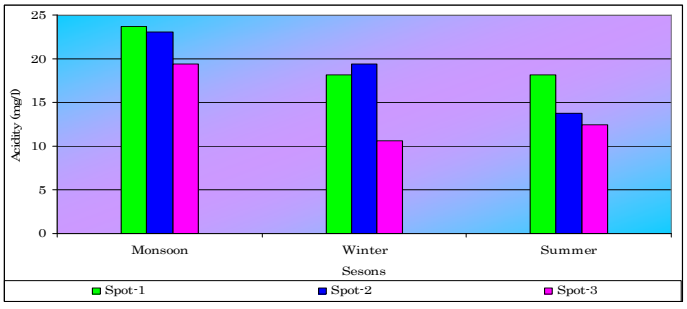

Figure-60
Seasonal variations in acidity at three spots in the Goriganga river during 2006-07

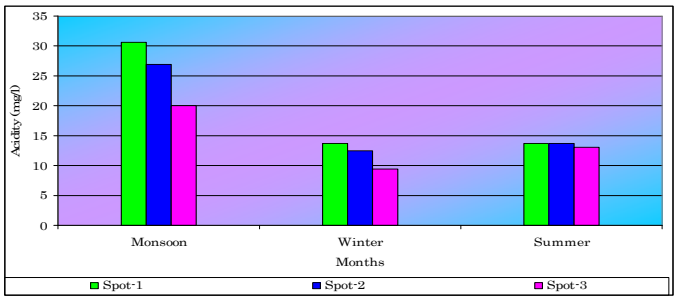

Figure-61
Seasonal variations in acidity at three spots in the Goriganga river during 2007-08

Water Hardness: The hardness of water of Goriganga river ranged from 80 mg/l to 166 mg/l in the first year (2006-07) while it increased in the second year which range between 90 mg/l to 198 mg/l in the present study table 23 and figurts-62, 63. The values of hardness at different sampling spots (Jauljibi, Baram and Madkot) in the Goriganga river were observed, fluctuating month wise, season wise, year wise and altitudinally in the present study tables 23, 24 and figures-62, 63, 64, 65. Monthly, the highest values of hardness were recorded as, 166 mg/l and 156 mg/l in the month of September at spot-1 and spot-2 and 138 mg/l in the month of March at spot-3 during first year table-23 and figure-62, and the minimum values of hardness were recorded in the month of July (82 mg/l, 84 mg/l and 80 mg/l) at spot-1, spot-2 and spot-3 respectively table 23 and figure- 62. In the second year (2007-08), the highest values of hardness were recorded in the month of October (198 mg/l, 194 mg/l and 180 mg/l) whereas the lowest values of hardness were recorded in the month of June (90 mg/l, 92 mg/l and 90 mg/l) at spot-1, spot-2 and spot-2 respectively table-23 and figure-63. The data of seasonal mean values of hardness have shown an increasing trend from winter (135.5 mg/l and 117.5 mg/l) to summer (138.5 mg/l and 121.5 mg/l) at spot-1 and spot-3 and from summer (129 mg/l) to winter (133 mg/l) at spot-3 during first year table-24 and figure-64. In the subsequent second year (2007-08), it showed an increasing trend from monsoon (135.5 mg/l, 135 mg/l and 127.5 mg/l) to winter (162.5 mg/l, 159 mg/l and 149.5 mg/l) at spot-1, spot-2 and spot-3 respectively table-24 and figure-65. It was also observed that highest seasonal mean values of hardness were recorded in summer (138.5 mg/l and 121.5 mg/l) at spot-1 and spot-3, whereas it was (133 mg/l) in winter at spot-3, while the lowest seasonal mean values were recorded in monsoon (124 mg/l, 120.5 mg/l and 107 mg/l) at spot-1, spot-2 and spot-3, respectively during first year table-24 and figure-64. But in the second year (2007-08), the highest seasonal mean values were recorded in winter (162.5 mg/l, 159 mg/l and 149.5 mg/l) and the lowest seasonal mean values of hardness were recorded in summer (130 mg/l, 127 mg/l and 126.5 mg/l) at spot-1, spot-2 and spot-3, respectively in the present study table-24 and figure-65. On the yearly basis, the annual mean values of the concerned parameter were recorded to be the highest mean values (132.66 mg/l and 142.66 mg/l) at spot-1, whereas the lowest annual mean values of hardness (115.33 mg/l and 134.5 mg/l) were recorded at Madkot during first and second year

respectively in the present study table-23. The data at different sampling stations also indicated that the few abrupt changes in the first year than in the second year. Altitudinally, the hardness of water has been increasing from upstream to downstream in the present study table-23. It was also observed that hardness of water at different spots in the Goriganga river was higher during second year (2007-08) than the previous year table-23 and figures-62, 63.

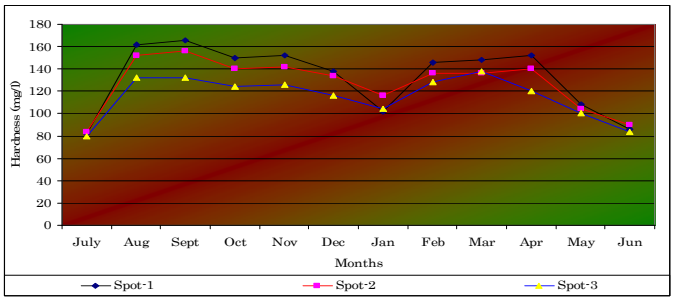

Figure-62
Monthly variations in hardness at three spots in the Goriganga river during 2006-07

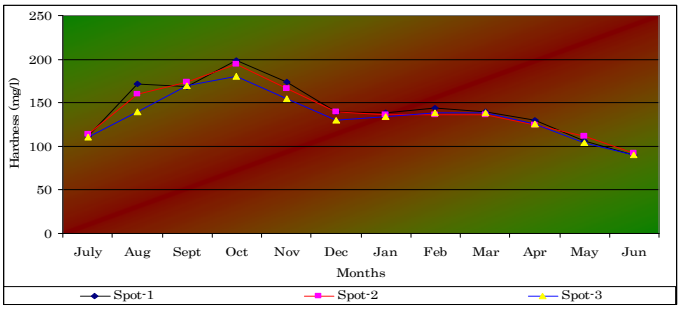

Figure-62
Monthly variations in hardness at three spots in the Goriganga river during 2007-08

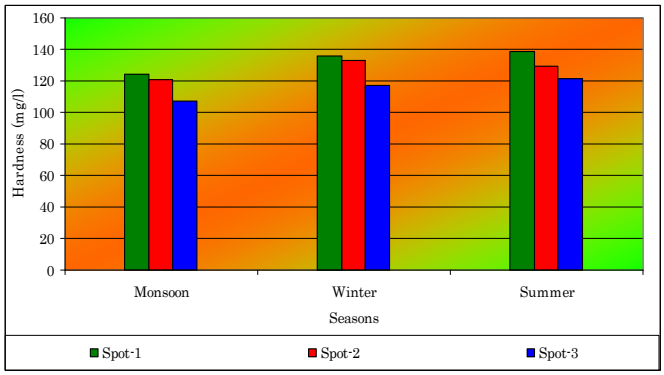

Figure-64
Seasonal variations in Hardness at three spots in the Goriganga river during 2006-07

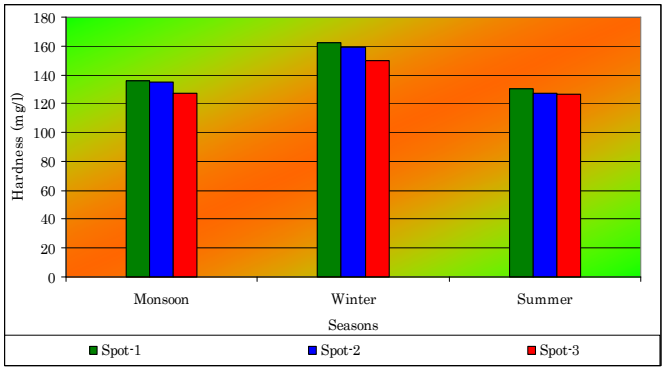

Figure-65
Seasonal variations in Hardness at three spots in the Goriganga river during 2007-08

Table-23
Monthly variations in water hardness at three spots in the Goriganga river during 2006-07 and 2007-08

Months	Water Hardness (mg/l)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)	Jauljibi (Spot-1)	Baram (Spot-2)	Madkot (Spot-3)
July	82	84	80	112	114	110
Aug	162	152	132	172	160	140
Sept	166	156	132	168	174	170
Oct	150	140	124	198	194	180
Nov	152	142	126	174	166	154
Dec	138	134	116	140	140	130
Jan	102	116	104	138	136	134
Feb	146	136	128	144	136	138
Mar	148	136	138	140	136	138
Apr	152	140	120	130	124	126
May	108	104	100	106	112	104
Jun	86	90	84	90	92	90
Mean	132.66	127.5	115.33	142.66	140.33	134.5
S.D.	27.778	23.558	19.151	31.337	28.943	25.882

Table-24
Seasonal variations in Water hardness (mg/l) at three spots (Jauljibi, Baram and Madkot) in the Goriganga river during 2006-07 and 2007-08

Water hardness (mg/l)						
Season	**2006-2007**			**2007-2008**		
	Spot-	**Spot-**	**Spot-**	**Spot-**	**Spot-**	**Spot-**
Monsoon	124	120.5	107	135.5	135	127.5
Winter	135.5	133	117.5	162.5	159	149.5
Summer	138.5	129	121.5	130	127	126.5

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